LMS/RFS/S15528

Fourth Five-Year Review Report for the Rocky Flats Site Jefferson County, Colorado

July 2017

PRELIMINARY DRAFT FOR WORKING GROUP REVIEW
(Not edited) 6/26/2019

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Approved by: Date:

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U.S. Department of Energy, Office of Legacy Management

Concurrence Letter Enclosed
U.S. Environmental Protection Agency

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Abbreviations

AOC	Area of Concern
AOI	analyte of interest
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances Disease Registry
CAD/ROD	Corrective Action Decision/Record of Decision
CCR	*Code of Colorado Regulations*
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CGP	construction general permit
CHWA	Colorado Hazardous Waste Act
COC	contaminant of concern
CR	Contact Record
CRA	Comprehensive Risk Assessment
CRS	Colorado Revised Statutes
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ETPTS	East Trenches Plume Treatment System
EUR	Environmental Use Restriction
FR	*Federal Register*
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
IRIS	Integrated Risk Information System
LM	Office of Legacy Management
µg/L	micrograms per liter
m^3	cubic meter

M&M	monitoring and maintenance
MCL	maximum contaminant level
MDC	maximum detected concentration
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mrem	millirems
MSPTS	Mound Site Plume Treatment System
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NWP	nationwide permit
O&M	operation and maintenance
OLF	Original Landfill
OU	Operable Unit
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential contaminant of concern
PLF	Present Landfill
PLFTS	Present Landfill Treatment System
PMJM	Preble's meadow jumping mouse
POC	Point of Compliance
POE	Point of Evaluation
PQL	practical quantitation limit
PRG	preliminary remediation goal
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RFI	RCRA Facility Investigation
RFLMA	Rocky Flats Legacy Management Agreement
RFSC	Rocky Flats Stewardship Council
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SPPTS	Solar Ponds Plume Treatment System

TCE	trichloroethene
TEDE	total effective dose equivalent
UCL	upper confidence level
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
UU/UE	unlimited use/unrestricted exposure
VOC	volatile organic compound
WQCC	Water Quality Control Commission
WQCD	Water Quality Control Division
WRV	wildlife refuge visitor
WRW	wildlife refuge worker

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Executive Summary

This fourth five-year review report documents the evaluation of remedial actions implemented at the Rocky Flats site located near Denver, Colorado. The purpose of the five-year review (FYR) is to evaluate the implementation and performance of the remedy to determine if the remedy is, and will continue to be, protective of human health and the environment.

The Rocky Flats site is located approximately 16 miles northwest of Denver and 10 miles south of Boulder in Colorado**Error! Reference source not found.**. The site was established in 1951 as art of the nuclear weapons complex to manufacture nuclear weapons components under the jurisdiction and control of DOE and its predecessor agencies. Manufacturing activities, accidental industrial fires, spills, and support activities resulted in the release of hazardous constituents to air, soil, sediment, groundwater, and surface water at the site. Contaminants released to the environment from activities at Rocky Flats included radionuclides such as plutonium, americium, and various uranium isotopes; organic solvents such as TCE, PCE, and carbon tetrachloride; metals such as chromium; and nitrates.

The Rocky Flats site was listed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) in 1989. The site was closed in 2005 following accelerated remedial actions. The final remedy of institutional and physical controls and continued monitoring, was selected in the 2006 Corrective Action Decision/Record of Decision (CAD/ROD). In 2007, the *Rocky Flats Legacy Management Agreement* (RFLMA), between DOE, the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE) was signed, which provides the implementing regulatory framework for the remedy.

The Rocky Flats site has two operable units within the boundaries of the property: the 1308-acre Central Operable Unit (COU) and the 4883-acre Peripheral Operable Unit (POU). The COU contains the areas of the site that required additional remedial/response actions. The POU includes the remaining, generally unimpacted portions of the site, and surrounds the COU. The Offsite Areas associated with the Rocky Flats site, known as OU 3, were addressed under a separate no action CAD/ROD dated June 3, 1997. Conditions in OU 3 and the POU allow for unlimited use and unrestricted exposure and were not evaluated in this FYR. These two OUs were deleted from the NPL in May 2007.

Because remaining contamination in the COU does not allow for unlimited use and unrestricted exposure, CERCLA requires that a periodic review be conducted at least every five years to determine whether the COU remedial actions remain protective of human health and the environment. This fourth FYR report covers remedy implementation at the COU for the period January 2012 through December 2016. Table ES-1 1 presents the remedial action objectives (RAOs) established in the CAD/ROD, the remedy components that support the RAOs, and the current remedy status.

Protectiveness Determination

The COU remedy was reviewed according to the 2001 EPA Comprehensive FYR Guidance which outlines a review process that includes community involvement, document and data

review, site inspections, and a technical assessment of the protectiveness of a remedy. The three questions examined during the technical assessment are:

A. Is the remedy functioning as intended by the decision documents?

B. Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives used at the time of remedy selection still valid?

C. Has any other information come to light that could call into question the protectiveness of the remedy?

The outcome of this FYR is a statement of protectiveness for the COU.

Protectiveness Statement

The remedy for the COU is currently protective of human health and the environment because institutional and physical controls are in place and effective in preventing unacceptable exposures. Continued surface and groundwater monitoring data and remedy inspections and maintenance required by the CAD/ROD further support long-term protectiveness.

Table ES-1 1. Remedial Action Objectives and Remedy Status

RAO	Remedy		Remedy Status
Groundwater			
1. Meet groundwater quality standards, which are the Colorado Water Quality Control Commission surface water standards, at groundwater AOC wells.	Institutional and Physical Controls: • Perimeter signage • Building construction prohibited • Excavation, drilling, digging restrictions • Drinking/agricultural SW use prohibited • GW well drilling prohibited • Any activities that interfere with remedy actions prohibited except when in accordance with RFLMA.	• GW monitoring at AOC wells • GW monitoring at Sentinel wells • Monitoring & maintenance of GW systems. • GW treatment before release to SW	Complete, in place and protective in the long-term.
2. Restore contaminated groundwater that discharges directly to surface water as base flow, and that is a significant source of surface water, to its beneficial use of surface water protection wherever practicable in a reasonable timeframe. This is measured at groundwater Sentinel wells. Prevent significant risk of adverse ecological effects.			
3. Prevent domestic and irrigation use of groundwater contaminated at levels above MCLs.			
Surface Water			
1. Meet surface water quality standards, which are the Colorado Water Quality Control Commission surface water standards.	• ICs listed above	• SW monitoring at POCs	Complete, in place and protective in the long-term.
Soil			
1. Prevent migration of contaminants to groundwater that would result in exceedances of groundwater RAOs.	• ICs listed above	• GW monitoring at Sentinel wells • GW treatment before release to SW	Complete, in place and protective in the long-term.
2. Prevent migration of contaminants that would result in exceedances of surface water RAOs.		• Prevent GW to SW migration • Repair and maintenance of landfills covers, vegetation • Ongoing protection of remedy components	
3. (Part 1) Prevent exposures that result in an unacceptable risk to the WRW. The 10-6 risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at the site or multiple pathways of exposure (40 *Code of Federal Regulations* 300.430[e][2][i][A][2]).		• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components	
3. (Part 2) Prevent significant risk of adverse ecological effects.		• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components	

Five-Year Review Summary Form

SITE IDENTIFICATION		
Site Name: Rocky Flats Site		
EPA ID: CO7890010526		
Region: 8	**State:** CO	**City/County:** Golden/Jefferson County
SITE STATUS		
NPL Status: Final		
Multiple OUs? No	**Has the site achieved construction completion?** Yes	
REVIEW STATUS		
Lead agency: Other Federal Agency **If "Other Federal Agency" was selected above, enter Agency name:** U.S. Department of Energy		
Author name (Federal or State Project Manager): Scott Surovchak, Site Manager		
Author affiliation: U.S. Department of Energy, Office of Legacy Management		
Review period **: June 10, 2016 – June 20, 2017		
Date of site inspection: March XX, 2017		
Type of review: Statutory		
Review number: 4		
Triggering action date: July 30, 2012		
Due date *(five years after triggering action date)*: August 3, 2017		
**** Review period is the start and end date of the FYR in WasteLAN.**		

OUs not Evaluated in this Five-Year Review:
The Peripheral OU and OU3, Offsite Areas, were not evaluated in this FYR. However, changes in risk assessment factors that occurred during this FYR period were evaluated for these two OUs. Conditions in these OUs continue to allow for unlimited use and unrestricted exposure and as a result, these OUs were not further evaluated in this FYR report.

Operable Unit:	***Protectiveness Determination:***	***Addendum Due Date (if applicable):***
COU	Protective	Not Applicable
Protectiveness Statement: The remedy for the COU is protective of human health and the environment and institutional controls are working to prevent unacceptable exposure to site contaminants.		

1.0 Introduction

This fourth five-year review (FYR) report documents the evaluation of remedial actions implemented at the Rocky Flats site located near Denver, Colorado. The purpose of the FYR is to evaluate the implementation and performance of the remedy to determine if the remedy is, and will continue to be, protective of human health and the environment. This FYR was conducted pursuant to CERCLA Section 121 and the National Contingency Plan (NCP). The FYR team consists of the U.S. Department of Energy Office of Legacy Management (DOE-LM) as the lead agency, the Environmental Protection Agency (EPA) Region 8, and the Colorado Department of Public Health and the Environment (CDPHE). This FYR covers remedy implementation at the Central Operable Unit (COU) for the period January 2012 through December 2016. The cutoff date for inclusion of environmental monitoring data is for samples collected as of December 31, 2016 (unless monitoring data results for later sample dates are noted in this report), to allow use of validated data.

The Rocky Flats site is located approximately 16 miles northwest of Denver and 10 miles south of Boulder in Colorado (Figure 1 inset). The site was established in 1951 as part of the nuclear weapons complex to manufacture nuclear weapons components under the jurisdiction and control of DOE and its predecessor agencies. Manufacturing activities, accidental industrial fires and spills, and support activities resulted in the release of hazardous constituents to air, soil, sediment, groundwater, and surface water at the site. Contaminants released to the environment from activities at the Rocky Flats site included radionuclides such as plutonium, americium, and various uranium isotopes; organic solvents such as TCE, PCE, and carbon tetrachloride; metals such as chromium; and nitrates.

2.0 Background

This section presents a brief summary of major actions undertaken at the Rocky Flats site under CERCLA. A chronology of site activities is presented in Appendix A and additional information on the history of the site may be found in the *Third Five-Year Review Report for the Rocky Flats Site* (DOE, EPA, and CDPHE, 2012b).

Investigation and cleanup of the Rocky Flats site (the Site) began in the 1980s, while the site was still an active industrial plant. In 1989, the Site was placed on the CERCLA National Priorities List (NPL). Soon thereafter, the Site mission transitioned from nuclear production to cleanup and closure. Considerable remediation of the Rocky Flats site took place during the late 1990s and early 2000s under the auspices of Rocky Flats Cleanup Agreement (RFCA). This agreement, signed by DOE, EPA, and CDPHE, adopted an accelerated action approach to site cleanup. DOE completed cleanup and closure of the Site in 2005. A *RCRA Facility Investigation – Remedial Investigation/Corrective Measures Study – Feasibility Study* (RI/FS Report) (DOE 2006a) was then completed that analyzed Site conditions after cleanup. The primary contaminants, contaminated media, and waste remaining at the Site include:

- Wastes disposed in two closed landfills: the Present Landfill (PLF), and the Original Landfill (OLF).
- Some subsurface soils with residual volatile organic compounds (VOCs), metals, and radionuclides and areas where former building and infrastructure components, debris, and

incinerator ash remain well below the surface with low levels of uranium, plutonium, and americium.

- Areas of groundwater that comprise contaminant plumes that contain VOCs, nitrates, and uranium at levels above surface water quality standards.
- Areas of surface soil contaminated with low levels of plutonium and americium.
- Some subsurface areas with VOC contamination at levels that could lead to inhalation of unacceptable VOC concentrations by building occupants if buildings were constructed in these areas.

The RI/FS included a comprehensive risk assessment that calculated the risks posed by residual contaminants to the anticipated future land users and evaluated alternatives for the final remedial action. Based on the RI/FS, the Site boundaries were reconfigured into two operable units (OUs): the COU, which included all areas that might require controls or further remedial action and the Peripheral OU (POU), which comprised areas that would likely not require further action or controls. The final remedy for each OU was selected in the 2006 Corrective Action Decision/Record of Decision (CAD/ROD). The selected remedy for the COU was institutional controls and physical controls with continued monitoring and maintenance. In 2007, the *Rocky Flats Legacy Management Agreement* (RFLMA) was signed by DOE, EPA, and CDPHE (DOE, EPA, and CDPHE 2007). This agreement superseded the RFCA and provided the implementing regulatory framework for the COU remedy. Attachment 2 to the RFLMA (Appendix B) specifies remedy performance standards, monitoring, inspection, and maintenance requirements, criteria for evaluating monitoring and inspection results, and reporting requirements.

The selected remedy for the POU in the 2006 CAD/ROD was no action, because this OU met the criteria for unlimited use/unrestricted exposure (UU/UE). The majority of land comprising the POU was transferred to the U.S. Fish and Wildlife Service (USFWS) in July 2007 for the purposes of establishing the Rocky Flats National Wildlife Refuge. An additional OU associated with Rocky Flats site known as the Offsites Areas (OU3), was addressed in a separate no action CAD/ROD dated June 3, 1997 (DOE, EPA, and CDPHE 1997). This OU also met the conditions to allow for UU/UE. Conditions in the POU and OU3 were assessed to ensure that changes to risk assessment factors did not adversely impact the UU/UE determinations for these OUs. This assessment concluded that the determination of UU/UE at the POU and OU3 is still valid. A summary of this assessment is provided in Appendix C. Because the UU/UE determinations remain applicable at OU3 and the POU, these OUs were not evaluated in this FYR.

This FYR was conducted for the COU only. Throughout the remainder of this document, unless otherwise noted, the Rocky Flats site (the Site or Rocky Flats) is meant to convey the land area encompassing the COU.

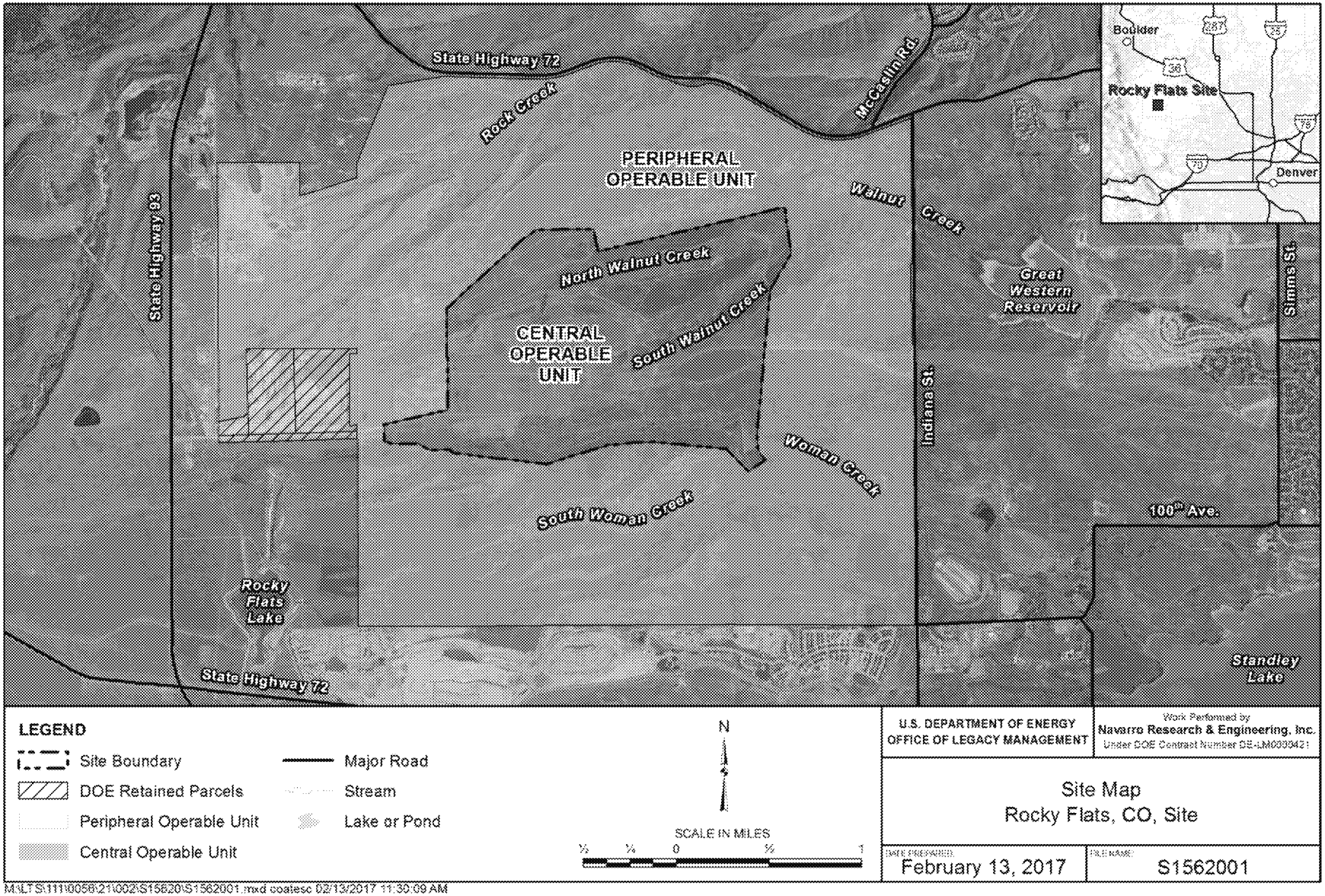

Figure 1. Site Map

3.0 Remedial Actions

3.1 Remedial Action Objectives

Remedial action objectives (RAOs) are the remediation goals a remedial action is designed to achieve. The RAOs for the Rocky Flats COU were developed for groundwater, surface water and soil and are presented in the CAD/ROD (DOE, EPA, and CDPHE 2006). The remedy components selected in the CAD/ROD that support the RAOs include institutional and physical controls, surface and groundwater monitoring, and maintenance of remedy engineered structures (e.g., landfill covers, groundwater treatment systems). The RAOs and components of the remedy that are pertinent to achieving each RAO are shown in Table 1.

3.2 Remedy Selection

The selected remedy for the COU is institutional and physical controls, incorporating continued monitoring and maintenance (DOE, EPA, and CDPHE 2006). Institutional controls prohibit soil disturbance activities not authorized by DOE, activities that could damage the landfill covers or other remedy components, construction of buildings for human occupancy, and the non-remedy-related use of surface water or groundwater (Table 2). Physical controls consist of signs listing the institutional controls and contact information posted at access points to the COU, and signs prohibiting unauthorized access posted around the COU perimeter. Monitoring at the COU includes sampling and analysis of groundwater and surface water at specified locations and frequencies; inspection and maintenance of the OLF and PLF covers and groundwater treatment systems; and inspection of institutional and physical controls. The CAD/ROD notes that further, routine monitoring of air, soil, sediment, or ecological resources is not required (DOE, EPA, and CDPHE 2006).

3.3 Remedy Implementation

3.3.1 Regulatory Framework

The requirements of the remedy are implemented in accordance with RFLMA and through an environmental covenant incorporating the institutional controls for the COU granted by DOE to CDPHE. RFLMA outlines the consultative process to be followed in implementing the agreement. The consultative process is initiated for all reportable conditions defined in RFLMA or at the request of RFLMA parties. As stated in RFLMA, "The objective of the consultation will be to determine a course of action to address the reportable condition and to ensure the remedy remains protective" (DOE, EPA, and CDPHE 2007). The outcome of consultation is documented in RFLMA contact records, which are made available to the public on the Rocky Flats website and made part of the post-closure Administrative Record. Appendix D provides a list of RFLMA contact records documented since the inception of RFLMA and a copy of the contact records referenced in this FYR report. Contact records from previous years may be obtained at http://www.lm.doe.gov/Rocky_Flats/ContactRecords.aspx.

Table 1. Remedial Action Objectives and Remedy Summary

RAO	Remedy
Groundwater	
1. Meet groundwater quality standards, which are the Colorado Water Quality Control Commission surface water standards, at groundwater AOC wells.	• GW monitoring at AOC wells
2. Restore contaminated groundwater that discharges directly to surface water as base flow, and that is a significant source of surface water, to its beneficial use of surface water protection wherever practicable in a reasonable timeframe. This is measured at groundwater Sentinel wells. Prevent significant risk of adverse ecological effects.	• GW monitoring at Sentinel wells • Monitoring & maintenance of GW treatment systems • GW treatment prior to reaching SW
3. Prevent domestic and irrigation use of groundwater contaminated at levels above MCLs.	• Institutional and Physical Controls
Surface Water	
1. Meet surface water quality standards, which are the Colorado Water Quality Control Commission surface water standards.	• SW monitoring at POCs
Soil	
1. Prevent migration of contaminants to groundwater that would result in exceedances of groundwater RAOs.	• GW monitoring at Sentinel wells • GW treatment prior to reaching SW
2. Prevent migration of contaminants that would result in exceedances of surface water RAOs.	• Repair and maintenance of landfills covers, vegetation • Ongoing protection of remedy components
3. (Part 1) Prevent exposures that result in an unacceptable risk to the WRW. The 10-6 risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at the site or multiple pathways of exposure (40 *Code of Federal Regulations* 300.430[e][2][i][A][2]).	• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components • Institutional and Physical Controls
(Part 2) Prevent significant risk of adverse ecological effects.	• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components

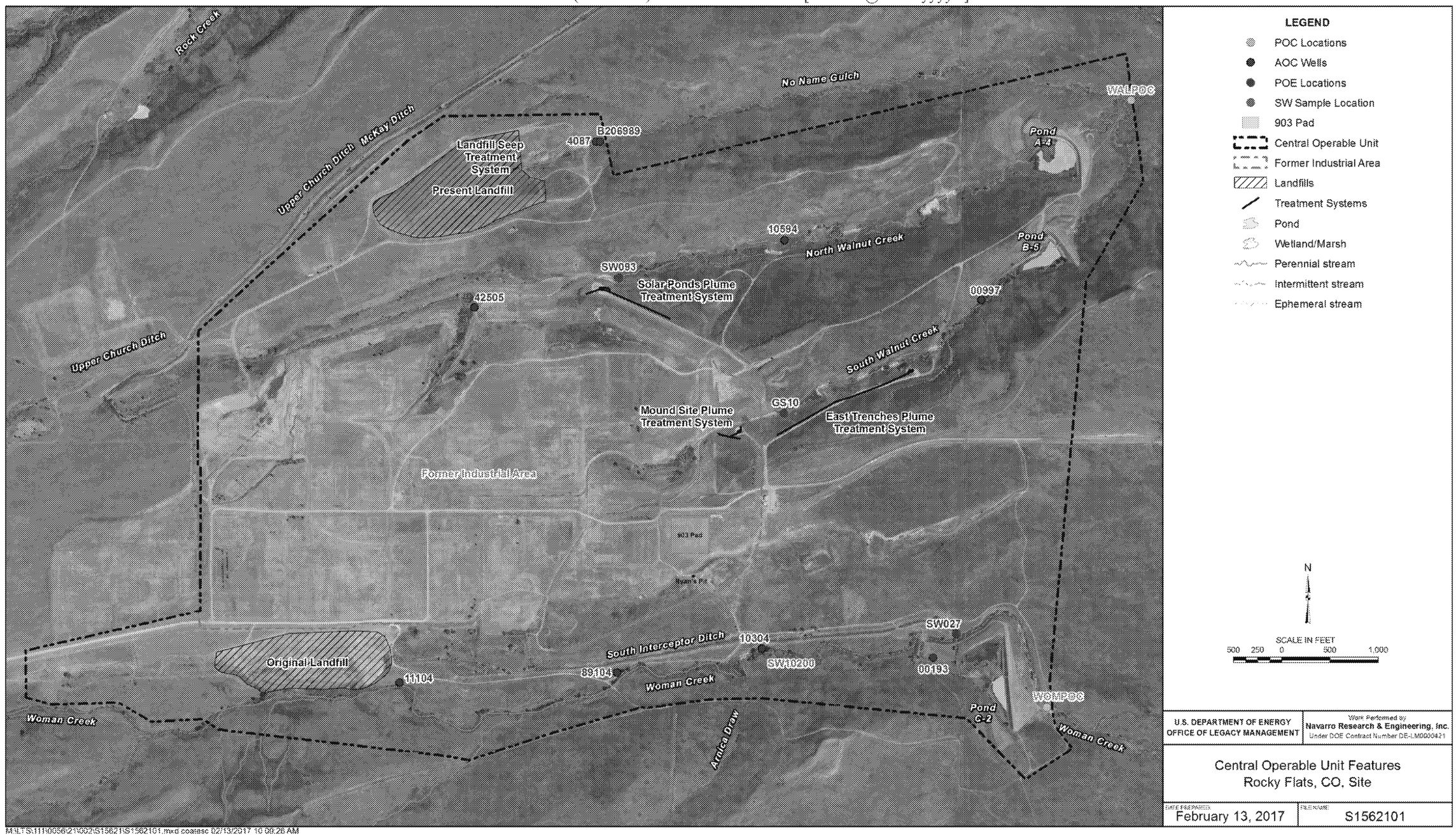

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Figure 2. Central Operable Unit Features

Table 2. Institutional Controls

Controls	Use Restrictions
1	The construction and use of buildings that will be occupied on a permanent or temporary basis (such as for residences or offices) is prohibited. The construction and use of storage sheds or other, non-occupied structures is permitted, consistent with the restrictions contained in controls 2 and 3 below, and provided such use does not impair any aspect of the response action at Rocky Flats.
	Objective: Prevent unacceptable exposures via the indoor air pathway. **Rationale:** The analysis of the indoor air pathway in the Comprehensive Risk Assessment indicated that subsurface volatile organic compounds were at levels in certain portions of the COU that could pose a risk of unacceptable exposure to the WRW if occupied structures were built in these areas.
2	Excavation, drilling, and other intrusive activities below a depth of three feet are prohibited, without prior regulatory review and approval pursuant to the Soil Disturbance Review Plan in RFLMA Attachment 2.
	Objective: Prevent unacceptable exposure to residual subsurface contamination. **Rationale:** Contaminated structures, such as building basements, exist in certain areas of the COU, and the Comprehensive Risk Assessment did not evaluate the risks posed by exposure to this residual contamination. Thus, this restriction eliminates the possibility of unacceptable exposures. Additionally, it prevents damage to subsurface engineered components of the remedy.
3	No grading, excavation, digging, tilling, or other disturbance of any kind of surface soils is permitted, except in accordance with an erosion control plan (including Surface Water Protection Plans submitted to EPA under the Clean Water Act) approved by CDPHE or EPA. Soil disturbance that will not restore the soil surface to preexisting grade or higher may not be performed without prior regulatory review and approval pursuant to the Soil Disturbance Review Plan in RFLMA Attachment 2.
	Objective: Prevent migration of residual surface soil contamination to surface water. **Rationale:** Certain surface soil contaminants, notably plutonium-239/240, were identified in the fate and transport evaluation in the Remedial Investigation as having complete pathways to surface water if disturbed. This restriction minimizes the possibility of such disturbance and resultant impacts to surface water. Restoring the soil surface to preexisting grade maintains the current depth to subsurface contamination or contaminated structures.
4	Surface water may not be used for drinking water or agricultural purposes.
	Objective: Prevent unacceptable exposure to local surface water contamination above the terminal ponds. **Rationale:** While the Comprehensive Risk Assessment did not evaluate the risks posed by the use of surface water for drinking or agricultural purposes, the nature and extent of contamination evaluation in the Remedial Investigation showed that certain contaminants were found at levels exceeding standards above the terminal ponds. This restriction reduces the possibility of unacceptable exposures to future users from this source.
5	The construction or operation of groundwater wells is prohibited, except for remedy-related purposes.
	Objective: Prevent unacceptable exposure to contaminated groundwater. **Rationale:** While the Comprehensive Risk Assessment did not evaluate the risks posed by the use of groundwater for drinking or agricultural purposes, the nature and extent of contamination evaluation in the Remedial Investigation identified areas in the COU where groundwater contaminants exceeded water quality standards or MCLs. This restriction reduces the possibility of unacceptable exposures to future users from this source. Additionally, it prevents the disruption of groundwater flow paths so as to avoid impacts on groundwater collection and treatment systems.
6	Digging, drilling, tilling, grading, excavation, construction of any sort (including construction of any structures, paths, trails or roads), and vehicular traffic are prohibited on the covers of the Present Landfill and the Original Landfill, except for authorized response actions.
	Objective: Ensure the continued proper functioning of the landfill covers. **Rationale:** This restriction helps ensure the integrity of the landfill covers.
7	Activities that may damage or impair the proper functioning of any engineered component of the response action, including but not limited to any treatment system, monitoring well, landfill cap, or surveyed benchmark, are prohibited. The preceding sentence shall not be construed to prohibit the modification, removal, replacement, or relocation of any engineered component of the response action in accordance with the action determinations in RFLMA Attachment 2.
	Objective: Ensure the continued proper functioning of engineered portions of the remedy. **Rationale:** This restriction helps ensure the integrity of other engineered components of the remedy, including monitoring and survey points.

1 Incorporates changes as a result of the 2011 CAD/ROD amendment (DOE, EPA, and CDPHE 2011).

RFLMA Attachment 2 was formally modified in December 2012 to incorporate changes agreed to by the RFLMA Parties (CR 2012-03). Additional modifications to RFLMA were approved by the regulators in CR 2014-02, which consisted of the deletion of surface water monitoring locations GS01 on Woman Creek and GS03 on Walnut Creek as POCs from the text and tables. Formal modification of the RFLMA in accordance with this CR is expected to occur during the next FYR period. The *Present Landfill Monitoring and Maintenance Plan and Post-Closure Plan* (PLF M&M Plan) (DOE 2008a) and the *Original Landfill Monitoring and Maintenance Plan, Rocky Flats Site* (OLF M&M Plan) (DOE 2009b) are incorporated by reference as enforceable requirements of RFLMA. The PLF M&M Plan was modified in February 2014 (CR 2014-03) and included the removal of PLF-specific vegetation and inspection requirements and associated revision to text, tables, and figures. The OLF M&M Plan was not modified during this FYR period, but is anticipated to be modified during the next FYR period.

One Explanation of Significant Differences (ESD) was issued during this FYR period. This ESD is documented in CR 2016-02, which was written to satisfy both RFLMA and CERCLA reporting requirements. The ESD/CR documents the change in location of groundwater treatment from the Mound Site Plume Treatment System (MSPTS) to the East Trenches Plume Treatment System (ETPTS). Previously, groundwater from the Mound plume and the East Trenches plume was treated in two separate treatment systems, located downgradient of each plume. The ESD/CR documented the reconfiguration of the MSPTS. This reconfiguration included the removal of the existing air stripper and zero valent iron (ZVI) treatment media and re-routing of groundwater to the ETPTS. The subsurface collection system for groundwater within the Mound plume was not altered.

3.3.2 Institutional and Physical Controls

The selected remedy in the CAD/ROD requires implementation of institutional and physical controls at the COU. The effectiveness of these controls is integral to the evaluation of groundwater, surface water, and soil RAOs (Table 1) and in determining protectiveness.

The institutional controls consist of a set of use restrictions that restrict or prohibit activities that may adversely impact the remedy and/or result in unacceptable exposures. These use restrictions were recorded in an Environmental Covenant between DOE and CDPHE in December 2006. The Covenant was modified in 2011 to clarify some use restriction language; no modifications were made during this fourth FYR period. The modified use restrictions are presented in Table 2. As recommended in the third FYR report, DOE and CDPHE are pursuing Environmental Use Restrictions (EURs) for the COU in accordance with Colorado Revised Statutes 25-15-318.5. Unlike the existing Environmental Covenant, the EURs will allow CDPHE to enforce the institutional controls necessary to maintain the protectiveness of the remedy in the long-term. EURs are binding on all current and future owners of the land and any persons possessing an interest in the land.

The physical controls implemented at the COU include signage located at access points and around the perimeter of the COU. DOE inspects the condition of signs and other physical controls on a quarterly basis.

DOE determines the effectiveness of the institutional controls described in RFLMA and the Environmental Covenant by inspecting the COU at least annually for any evidence of violations of those controls (see Section 5.4). DOE also annually verifies that the Environmental Covenant remains in the Administrative Record and on file with the Jefferson County Planning and Zoning Department.

3.3.3 Remedy Monitoring and Maintenance

The selected remedy in the CAD/ROD also requires environmental monitoring of groundwater and surface water and continued operation and maintenance of engineered remedy components (landfill covers and groundwater treatment systems).

The groundwater monitoring network is complete and sampling and analyses are being performed as required by RFLMA. The groundwater monitoring network includes four types of monitoring wells: AOC, Sentinel, Evaluation, and RCRA. The AOC wells provide data directly relevant to groundwater RAO 1; the Sentinel wells provide data directly relevant to groundwater RAO 2 and soil RAO 1 (Table 1). AOC wells are located downgradient of contaminant plumes and are monitored to determine if contaminants are discharging to surface water. Surface water monitoring location SW018 is monitored on the same routine schedule as the AOC wells to assess groundwater impacts to surface water from specific source areas in the COU. The locations of AOC wells and SW018 are shown on Figure 2. Sentinel wells are located near downgradient edges of contaminant plumes and downgradient of the groundwater treatment systems. These wells are monitored to determine if concentrations of contaminants are increasing, indicating possible plume migration or treatment system issues. A discussion of AOC and Sentinel well data as they relate to RAOs is presented in Section 6.1.2. Evaluation wells are located within groundwater contaminant plumes and near plume source areas. Data from these wells support various objectives, such as providing input to groundwater modeling efforts, modification of groundwater monitoring and/or treatment requirements, or evaluation of changing contaminant conditions as indicated by downgradient AOC or Sentinel wells. RCRA wells are located at the PLF and OLF and are used to monitor groundwater conditions upgradient and downgradient of each landfill.

The surface water monitoring network is complete and sampling and analysis are being performed as required by RFLMA. The surface water monitoring network includes three types of locations: points of compliance (POCs), points of evaluation (POEs), and performance monitoring locations. The two POCs are located at the eastern boundary of the COU in Woman and Walnut Creeks and are monitored to determine water quality before it leaves the COU. Data collected at the POCs are evaluated against surface water quality standards and are directly relevant to the surface water RAO 1 in Table 1. A discussion of POC data as it relates to this RAO is presented in Section 6.1.3. The three POEs are located upstream of the POCs and provide an early indication of potential downstream impacts at the POCs. The POC and POE locations are shown on Figure 2. Data collected at performance monitoring locations are used to determine the short- and long-term effectiveness of specific remedies (e.g., groundwater treatment systems). A map showing the performance monitoring locations is presented in Appendix E.

The engineered components of the remedy defined in the CAD/ROD consist of the PLF and OLF covers and the four groundwater treatment systems. Each engineered component has associated groundwater and surface water monitoring locations that support the evaluation of remedy performance. All remedy components are in place and operating in accordance with RFLMA.

- **Landfills:** At the OLF, the remedy consisted of construction of a 2-ft thick soil cover with a buttress at the tow of the landfill, and installation of perimeter drainage channels and cover diversion berms to control surface water run-on and runoff. The remedy at the PLF included a RCRA-compliant cover consisting of a geosynthetic composite cover with a rock layer, and surface water run-on and runoff controls. Inspection and maintenance requirements for the PLF and OLF are provided in the approved landfill Monitoring & Maintenance (M&M) Plans. Performance of the landfill cover systems is evaluated in relation to soil RAOs 2 and 3 (Table 1) and is discussed in Sections 6.1.4.1and 6.1.4.2
- **Groundwater treatment systems:** The remedy in the CAD/ROD incorporated the four passive groundwater treatment systems in place when the Site closed in 2006: Present Landfill Treatment System (PLFTS), Solar Ponds Plume Treatment System (SPPTS), Mound Site Plume Treatment System (MSPTS) and East Trenches Plume Treatment System (ETPTS). Optimization and reconfiguration of three of these treatment systems has taken place during this FYR period. Performance of these systems is evaluated in relation to groundwater RAO 2 and soil RAO 1 (Table 1) and is discussed in Sections 6.1.4.1 and 6.1.4.3.

4.0 Progress Since the Last Five-Year Review

The protectiveness statement from the third FYR report is as follows (DOE 2012b):

The remedy for the COU is protective of human health and the environment because surface water concentrations are meeting standards at points of compliance, and monitoring and maintenance plans and institutional controls are working to prevent unacceptable exposure to site contaminants.

The third FYR report identified four issues to be addressed in the next FYR period. Table 3 presents each issue and a summary of the status at the end of this FYR period. Three of the identified issues concerned reportable conditions for radionuclides at surface water POE monitoring locations. Additional detail regarding these POE reportable conditions is presented in Appendix E.

Based on the results of this fourth FYR, all issues from the third FYR have been satisfactorily addressed.

Table 3. Status of the Third FYR Report Recommendations

Issue	Follow-Up and Expected Completion Date	Status	Does Issue Affect Protectiveness?
Surface water Point of Evaluation (POE) GS10 uranium concentration periodically exceeded the RFLMA standard during the third FYR period and exceeds the standard at the end of the third review period. POEs are located upstream of surface water POCs at the edge of the former Industrial Area to provide early indication of potential contaminant migration.	The RFLMA consultative process is effective in determining whether, and to what extent, any mitigating action may be recommended, and to establish the schedule to complete actions. Uranium levels at GS10 are linked to seasonal low flow conditions and the influence of predominantly natural uranium in groundwater that contributes to base flow at GS10. Monitoring downstream of GS10 shows that conditions at GS10 do not and are not likely to result in exceedance of the RFLMA standard at the POC. Continue to monitor in accordance with RFLMA requirements. Complete work in accordance with the CDPHE- and EPA-approved evaluation plan.	The RFLMA standard for U has been exceeded at GS10 intermittently during this FYR period (see Appendix E). Figure E-1 illustrates the 12-month rolling averages for U at GS10. The exceedances and subsequent reportable conditions for U in this drainage system led to an extensive evaluation of the Walnut Creek drainage system (Wright Water Engineers, 2015). This evaluation identified natural processes that may be contributing to U increases in surface water, including the precipitation events in 2013 and 2015 (see Section 6.1.3). At the end of this fourth FYR period, the 12-month rolling average for U at GS10 does not exceed the RFLMA standard.	No. Consultation with the RFLMA parties on the reportable conditions for U at GS10 resulted in an evaluation plan for addressing the condition (CR 2011-04, 2011-05) to ensure the remedy remains protective.
Surface water POE GS10 americium concentration began to exceed the RFLMA standard in 2011 and exceeded the standard at the end of the third FYR period.	The RFLMA consultative process is effective in determining whether, and to what extent, any mitigating action may be recommended, and to establish the schedule to complete actions. Americium levels at GS10 may be linked to colloidal transport mechanisms or surface soil and sediment erosion mechanisms. Soil erosion does not appear to be a primary factor, since erosion is usually associated with heavy precipitation events and high flow conditions. The elevated americium levels have occurred generally during low flow conditions indicating colloidal transport at GS10. Monitoring downstream of GS10 shows that conditions at GS10 do not and are not likely to result in exceedance of the RFLMA standard at the POC. Continue to monitor in accordance with RFLMA requirements. Complete work in accordance with the CDPHE- and EPA-approved evaluation plan.	The RFLMA standards for Pu and Am have been exceeded at GS10 intermittently during this FYR period (see Appendix E). Figure E-2 illustrates the Pu and Am 12-month rolling averages at GS10. Evaluation of these reportable conditions did not yield a definitive cause for the exceedances. Monitoring locations downstream at GS08 and WALPOC did not exceed the standards during this time period. Pu and Am concentrations fell below RFLMA standards in 2014 and routine monitoring at GS10 recommenced. At the end of this fourth FYR period, the 12-month rolling averages for Am and Pu at GS10 do not exceed the RFLMA standard.	No. Consultation with the RFLMA parties on the reportable conditions for Am and Pu at GS10 resulted in an evaluation plan for addressing the condition (CR 2011-08) to ensure the remedy remains protective.

Issue	Follow-Up and Expected Completion Date	Status	Does Issue Affect Protectiveness?
Surface water POE SW027 plutonium concentration exceeded the RFLMA standard in 2010 during a high precipitation event. The standard was no longer exceeded at the end of the third FYR period.	The RFLMA consultative process is effective in determining whether, and to what extent, any mitigating action may be recommended, and to establish the schedule to complete actions. After mitigating actions to improve erosion controls in the drainage were completed in 2010, only very small volumes of infrequent, short-term, intermittent flows occurred at SW027. As a result, no samples were obtained for over a year. Because the RFLMA standard is based on 12- month rolling average of the results, and there were no sample results for averaging, the standard was no longer exceeded at the end of the third FYR review period (2012). Samples will be obtained when there is sufficient flow to evaluate the effectiveness of the mitigating measures. Continue to monitor in accordance with RFLMA requirements.	The RFLMA standards for Pu and Am have been exceeded at SW027 intermittently beginning in 2010 through the end of this FYR period (see Appendix E). Figure E-6 illustrates the Am and Pu 12-month rolling averages at SW027. The exceedances coincide with periods of increased runoff resulting from heavy precipitation. Evaluation of these reportable conditions suggest that Pu and Am move with particulates (DOE, 2013) and may be a result of soil erosion. Mitigation measures to control erosion originating from the contaminant source at the 903 Pad/Lip Area were completed in 2010, 2011, and 2015 following each reportable occurrence. Evaluation of upstream and downstream data does not indicate an unknown source of contamination. There have been no exceedances of Pu or Am at WOMPOC, located downstream of SW027, during this fourth FYR period.	No. Consultation with the RFLMA parties on the reportable conditions for Am and Pu at SW027 resulted in an evaluation plan for addressing the condition (CR 2015-05) to ensure the remedy remains protective.
Institutional controls might not be easily enforceable against a utility easement holder who is not a party to the Environmental Covenant. While this is not a near-term issue (because the Office of Legacy Management (LM) maintains a good working relationship with the current easement holder), the lack of enforceability could become an issue in the future if LM and the easement holder (or any successor) do not maintain routine contact.	Replace the Environmental Covenant with a restrictive notice under Colorado law, as provided for in the 2011 CAD/ROD amendment. While an environmental covenant might not be directly enforceable against a prior holder of an interest in land who is not a party to the covenant, a restrictive notice is enforceable by CDPHE against any person in violation of the institutional controls. DOE and CDPHE will consult with goal to replace the Environmental Covenant with a restrictive notice by end of 2012.	As of December 2016, the Environmental Use Restrictions (EURs) have not been adopted for the Site, but the process is well underway. However, the environmental covenant remains in place and effective in the short-term.	No. To date, there have been no incidences involving current easement holders that call into question the effectiveness of institutional or physical controls. A restrictive notice, however, would provide a means for enforcing these controls.

5.0 Five-Year Review Process

5.1 Community Notification and Involvement

Notification of commencement of the fourth FYR was distributed to Rocky Flats stakeholders via email and posted to the DOE-LM webpage on June 10, 2016. This notice included an overview of the FYR process, web links to the 2012 FYR report, site contact information, and the address to submit questions or comments related to the FYR.

The FYR team gave a public presentation on the fourth FYR at the June 6, 2016 Rocky Flats Stewardship Council[1] (RFSC) meeting, which was open to the public. The RFSC serves as a forum to promote community involvement with Rocky Flats, including the FYR. Other public communication tools include the DOE-LM website and stakeholder email listings. Notification of the RFSC FYR presentation was provided directly to stakeholders via email and was posted on the Rocky Flats and RFSC public websites prior to the meeting. The FYR presentation included an overview of the review process including community involvement, and a question and answer period.

In response to email questions regarding public review of the FYR report, an update to the initial June 2016 notification was provided on November 15, 2016. This notice was distributed to Rocky Flats stakeholders via email and posted to the DOE-LM webpage. The update clarified that while a formal public review and comment period for the FYR report was not included in the CERCLA FYR process, the public was invited to submit questions and input by way of the communication tools provided in the notice. The update contained several web links to EPA guidance on community participation in the FYR process and general information on FYRs. In order to meet the FYR report schedule, the update requested that public input be provided no later than December 31, 2016.

EPA guidance includes consideration of the need for interviews with local residents or other stakeholders to identify issues that might be included in the FYR. The RFLMA Parties keep the public and local community governments informed by making all RFLMA required reports and contact records available on the Rocky Flats public website, making quarterly presentations at RFSC meetings, holding periodic technical meetings with local community governments, and providing formal public review and comment periods as required for proposed RFLMA modifications and CAD/ROD amendments. Based on these continual public participation activities and the steps taken to inform the public about this review, the review team concluded specific interviews were not needed.

Written FYR input from stakeholders was received during the requested submittal period in the form of four formal letters. In addition, verbal input and questions from stakeholders were offered at RFSC and other stakeholder meetings. Stakeholder input was consolidated by topic, where possible, to remain consistent with past practices. A summary of this input and the responses provided by the FYR team are presented in Appendix I.

[1] The RFSC was formed in March 2006 and is managed by a Board of Directors. Membership includes elected officials from counties and cities surrounding Rocky Flats, as well as three community organizations and one individual. The Board of Directors meets quarterly and partners with DOE and USFWS to provide periodic updates to the community about issues related to Rocky Flats.

5.2 Document Review

Documents reviewed for this FYR are listed in Appendix F. Where appropriate, references to documents where additional information or data may be found were cited throughout this report.

5.3 Data Review

The CAD/ROD and RFLMA require regular, periodic monitoring of surface water and groundwater. The data from these monitoring activities are relevant in determining if the RAOs are being met. The RFLMA quarterly and annual reports contain monitoring and maintenance data pertaining to surface water and groundwater, the OLF and PLF, and the groundwater treatment systems. This information is used to assess the performance of the remedy over this FYR period.

Attachment 2 of RFLMA specifies the remedy performance standards and requirements for the selected remedy (Appendix B). These standards and requirements are enforceable numerical values or narrative description of conditions or restrictions, designed to protect existing or potential uses, against which remedy performance can be measured. These standards and requirements are derived from state surface water standards and from requirements established in the final CAD/ROD (e.g., landfill inspections). The remedy performance standards for surface water in the COU are found in Table 1 of Attachment 2 to RFLMA. Because groundwater flows into surface water prior to exiting the COU, the groundwater use classification at the COU is surface water protection. Thus, the numeric values for measuring potential effects of contaminated groundwater on surface water quality are also the surface water standards in Table 1 of Attachment 2 to RFLMA. Surface water and groundwater monitoring data are evaluated annually by comparing results to the Table 1 standards and conducting trend analyses. The results of these evaluations are presented in the quarterly and annual reports required by RFLMA.

If reportable conditions defined in RFLMA are identified as a result of data evaluation, the RFLMA parties (DOE, EPA and CDPHE) consult and develop a plan for evaluating and addressing the condition. During this fourth FYR period, reportable conditions were documented at the OLF (CR 2013-02), AOC well 10304 (CR 2015-10), POE SW027 (CR 2015-05), and the WALPOC (CRs 2014-05, 2015-01, 2016-01, 2017-02). These reportable conditions are discussed in Section 6.1 and Appendix E.

5.4 Site Inspections

EPA guidance indicates that the FYR should include a recent site inspection to visually confirm and document the conditions of the remedy, the site, and the surrounding area (EPA 2001). The CAD/ROD and RFLMA also requires an annual inspection of the COU, in addition to more frequent routine and weather-related inspections of remedy components at the PLF and OLF. During this FYR period, all routine inspections, and several weather-related inspections, were conducted and reported in accordance with RFLMA requirements.

This section summarizes the results of the annual inspections of the COU conducted during this FYR period; the results of routine and weather-related inspections at the PLF and OLF are summarized in Sections 6.1.4.1 and 6.4.1.2, respectively. Inspection results, including completed inspection forms, may be found in the Site quarterly and annual reports (add references).

Annual inspections of the COU were conducted in March or April during this FYR period. The most recent COU inspection was conducted on March XX, 2017. Representatives from DOE, EPA, and CDPHE participate in the annual inspections. Appendix G contains the inspection checklist and maps for the most recent inspection.

The following are assessed during the annual COU inspection:

- Evidence of significant erosion in the COU and evaluation of the proximity of significant erosion to subsurface features left in place at closure. This monitoring included visual observation for precursor evidence of significant erosion (e.g., cracks, rills, slumping, subsidence, sediment deposition);
- The effectiveness of institutional controls, as determined by any evidence of violation; and
- Evidence of adverse biological conditions, such as unexpected morbidity or mortality, observed during the inspection and monitoring activities.

Quarterly and weather-related inspections for erosion in areas where building features remain in the subsurface were completed as required during this FYR period. Evidence of subsidence near the locations of former buildings 771, 881, and 991 was noted in the 2015 annual site inspection (add reference). The openings ranged from 1 to 8 feet in width and 1 to 5 feet in depth. These areas were filled and graded shortly after discovery. In 2016, additional settling was noted in the former building 881 area where the subsidence had been filled the previous year. In response, this area was filled and graded.

No evidence of violations of institutional controls or physical controls was observed in any of the annual inspections. In conjunction with each annual inspection, the presence of the Environmental Covenant in the Administrative Record and Jefferson County records was verified. The most recent verification of the Environmental Covenant was completed on March x, 2017. The physical controls required by the remedy (i.e., signs at the COU boundary and access points) were inspected quarterly throughout this FYR period. A few signs were added or replaced and faded stickers were replaced, as needed. The signs continue to function as designed.

No adverse biological conditions were noted during any of the annual COU inspections during this FYR period.

6.0 Technical Assessment

This section documents the technical assessment of the performance of the remedy. This assessment includes:

- Consideration of monitoring and surveillance information reported in RFLMA quarterly and annual reports of site surveillance and maintenance activities,
- Information on post-remedy decision-making documented in RFLMA contact records and amendments or modifications to remedy requirements,
- Review of the status of the RAOs,
- Changes to the ARARs the remedy must attain,
- Changes to toxicity factors, exposure parameters, or assumptions that might affect the level of risk posed by residual contamination, and
- Any new information that may call into question the protectiveness of the remedy.

6.1 Question A: Is the Remedy Functioning as Intended by the Decision Documents?

Based on this FYR evaluation, the remedy is functioning as intended by the CAD/ROD (DOE, EPA, and CDPHE 2006):

- Institutional controls are in place and effective in meeting the objectives presented in Table 2. Physical controls are in place and effective.
- Required surface water and groundwater monitoring is ongoing and supports achievement of RAOs in the long-term.
- Operation and maintenance (O&M) of remedy components at the OLF, PLF, and groundwater treatment systems is ongoing and supports achievement of RAOs in the long-term.

6.1.1 Institutional and Physical Controls

The institutional and physical controls required by the remedy are in place and effective in preventing unacceptable exposures. The effectiveness of institutional controls is determined by annually inspecting the site for evidence of violations. Less formal inspections and observations are performed throughout the year by site staff as they perform regular monitoring and maintenance activities. An annual verification that the Environmental Covenant is in the Administrative Record and recorded in Jefferson County is also required. Annual inspections of the COU were completed in accordance with RFLMA. No evidence of institutional control violations was discovered. The presence of the Environmental Covenant in the Administrative Record and Jefferson County records was verified on March xx, 2017.

6.1.2 Groundwater Monitoring

The groundwater monitoring network in the COU consists of four types of wells: AOC, Sentinel, Evaluation, and RCRA. Data from groundwater monitoring at AOC and Sentinel wells are directly relevant to assessing remedy performance in relation to groundwater RAOs 1and 2 and Soil RAO 1. Remedy performance for the AOC and Sentinel wells is discussed in this section. Data from Evaluation wells are discussed in Appendix E; data from RCRA wells are discussed in Sections 6.1.4.1and 6.1.4.2.

6.1.2.1 AOC Wells

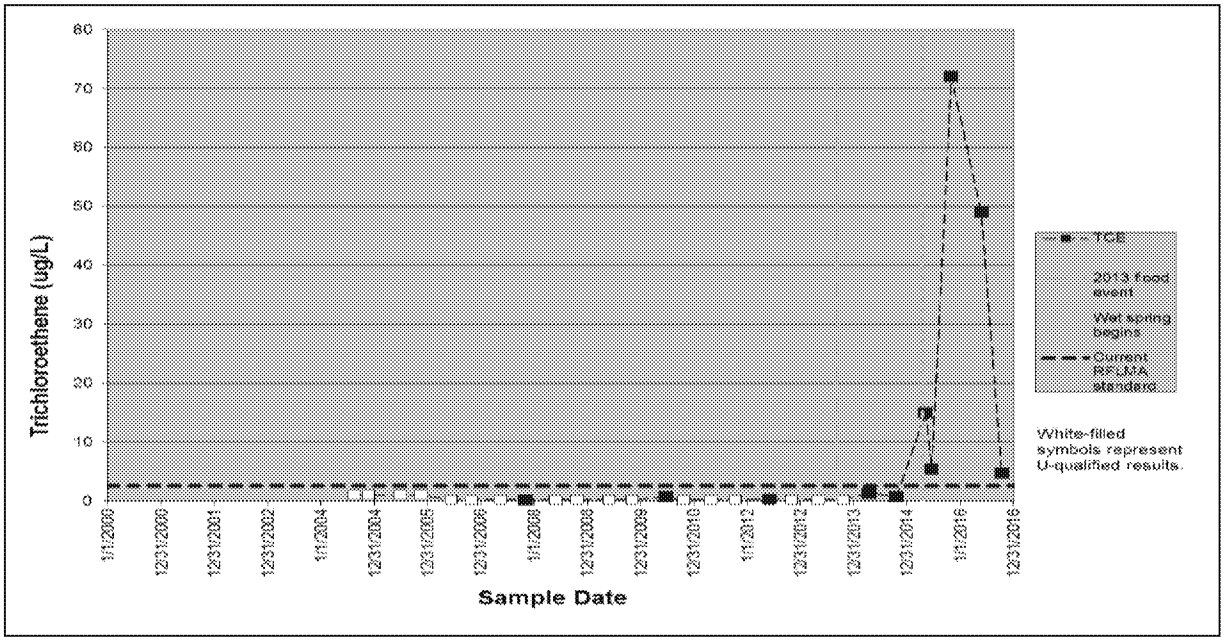
The existing AOC well network consists of 9 wells from which routine RFLMA monitoring samples are collected semiannually. Remedy performance is measured at AOC wells by an evaluation of the two most recent routine monitoring results as compared to RFLMA standards. The RFLMA Attachment 2 decision logic flowchart Figure 7, "Area of Concern Wells and SW018" (Appendix B), is relevant to these evaluations. If the results for an individual constituent in the two most recent routine samples are greater than its respective RFLMA standard, a reportable condition exists and consultation with EPA and CDPHE is required. There was one reportable condition at an AOC well during this FYR period. Trichloroethene (TCE) was detected in the two sampling results from AOC well 10304 in 2015 (CR 2015-10). The RFLMA standard for TCE is 2.5 µg/L and the sample results were 15 µg/L and 72 µg/L respectively in the second- and fourth-quarter 2015 groundwater samples. AOC well 10304 was installed in 2004 to evaluate groundwater quality adjacent to Woman Creek, downgradient of the 903 Pad/Ryan's Pit (Figure 2). As evidenced in Figure 3, TCE has been detected in this well previously, however, this is the first reportable condition at this well. TCE concentrations in this well are currently in decline, but remained reportable through 2016.

As required by RFLMA, DOE consulted with EPA and CDPHE and developed a plan for addressing the reportable condition. The plan included the collection of surface water samples from Woman Creek downgradient of well 10304, to assess any potential impacts to surface water quality. A surface water sample from downgradient Woman Creek location SW10200 (Figure 2) was collected in December 2015; TCE was not detected in this sample. Additional samples from this surface water location were collected concurrent with well 10304 semiannual sampling in 2016; TCE was not detected in these samples. TCE was detected in the two 2016 semiannual groundwater samples at 49 µg/L and 4.7 µg/L, which are both above the RFLMA TCE standard.

Increased concentrations of TCE in groundwater discharging to Woman Creek under conditions of higher-than-normal precipitation were predicted at Site closure. The potential for increased VOC concentrations during wet conditions is described in the *Final Interim Measure/Interim Remedial Action for Groundwater at the Rocky Flats Environmental Technology Site* (Kaiser-Hill 2005) and the *Fate and Transport Modeling of VOCs at the Rocky Flats Environmental Technology Site* (Kaiser-Hill 2004). Given that the spring of 2015 was exceptionally wet, the TCE results reported for AOC well 10304 are not unexpected. As site conditions get drier, it is anticipated that VOC concentrations in groundwater will decrease, as is the observed trend at well 10304.

As of the end of this FYR period, the most recent semiannual data show a TCE concentration above the RFLMA standard at AOC well 10304. Therefore, groundwater RAO 1is not currently being met at all AOC wells (Table 4). As stated in the CAD/ROD, the RAOs for each medium are interdependent and were developed based on this premise (DOE, EPA, and CDPHE 2006).

Because of the hydrologic connection of groundwater with surface water at the Site, it is therefore appropriate to assess surface water quality in combination with groundwater results in evaluating overall remedy protectiveness. The remedy remains protective in the long-term because: (1) the 2016 data suggest a decreasing trend in TCE concentration in this well, suggesting a short-term event, and (2) the reportable condition did not impact downstream surface water quality, as TCE was not detected in surface water samples from Woman Creek collected downgradient of the well.



Note: A temporary modification to the TCE standard was in effect for RF until the end of 2009. For simplicity, this standard is not shown on the figure above; instead, the current TCE water quality standard of 2.5 µg/L is presented.

Figure 3. TCE Concentrations at AOC Well 10304 (2004–2016)

6.1.2.2 Sentinel Wells

Sentinel wells are typically located near downgradient edges of contaminant plumes, in drainages, at groundwater treatment systems, and along contaminant pathways to surface water (Figure 4). These wells are monitored to determine whether concentrations of contaminants indicate plume migration or treatment system problems that may result in impacts to surface water quality. The existing Sentinel well network consists of 27 wells from which routine monitoring samples are collected semiannually. The RFLMA Attachment 2 decision logic flowchart Figure 8, "Sentinel Wells" (Appendix B), is relevant to these data. Groundwater quality in Sentinel wells at the end of this FYR period was generally consistent with conditions at the time of closure. Groundwater does not meet RFLMA standards for some VOCs, uranium, and nitrate at most Sentinel well locations. While there are no indications of significant plume migration that impact the continued protectiveness of the remedy, groundwater RAO 2 and soil RAO 1 are not currently being met at all Sentinel wells (Table 4). The CAD/ROD stated that no additional removal, containment, or treatment actions could be reasonably taken to address these RAOs at the time, and recognized that the remedial actions undertaken as a part of site closure were "not expected to eliminate groundwater contamination in the short term, but are expected to

have a positive long-term impact on groundwater and surface water quality" (DOE, EPA, CDPHE 2006). These statements remain valid for this FYR period and therefore, continued monitoring of the Sentinel wells is necessary.

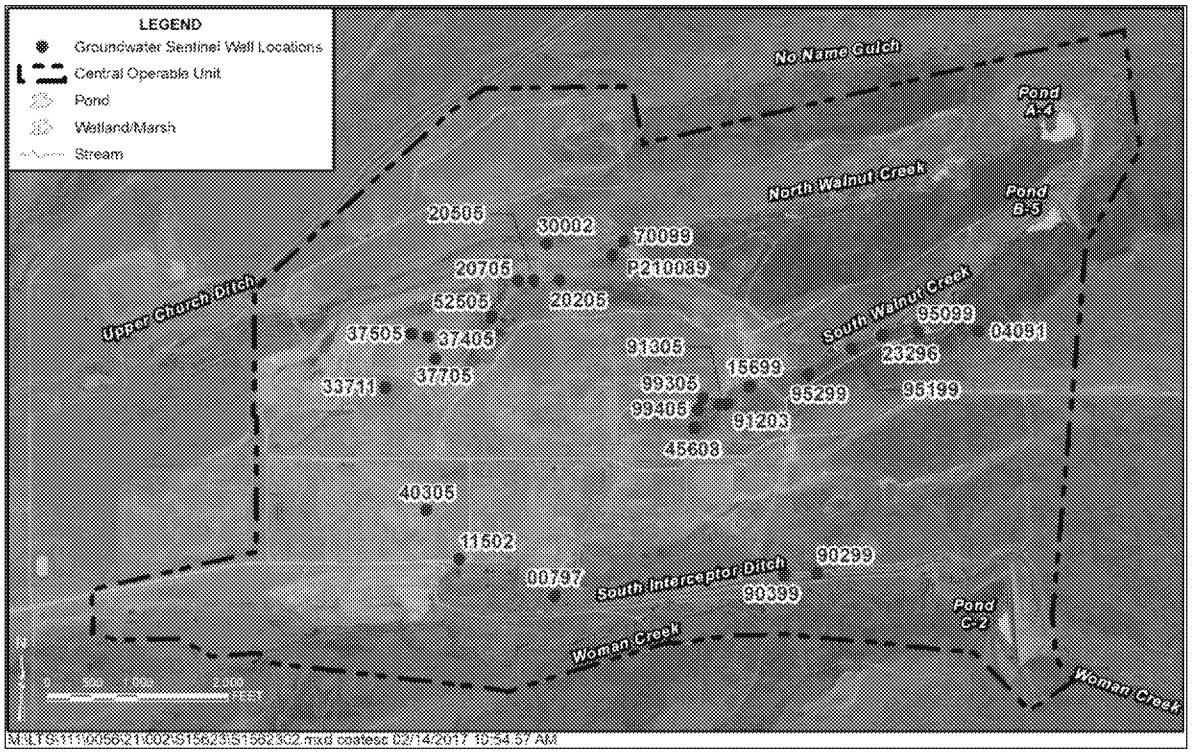


Figure 4. Sentinel Well Locations

6.1.3 Surface Water Monitoring

The surface water monitoring network in the COU consists of three types of locations: POCs, POEs, and performance monitoring locations. Data from surface water monitoring at POCs are directly relevant to assessing remedy performance in relation to surface water RAO 1 and are discussed in this section. Data from surface water monitoring at POEs and performance monitoring locations are discussed in Appendix E.

6.1.3.1 Points of Compliance

At the beginning of this FYR period, there were two POC locations outside the COU boundary adjacent to Indiana Street (locations GS01 and GS03). In January 2014, in consultation with the EPA and CDPHE, the POCs were moved upstream to the WOMPOC and WALPOC locations just inside the eastern boundary of the COU (see CR 2014-02 and Figure 2). The WOMPOC (within Woman Creek) and WALPOC (within Walnut Creek) surface water POCs are used to measure remedy performance against RFLMA surface water standards at the COU boundary prior to surface water leaving the COU. Remedy performance at the POCs is measured through a comparison of the volume-weighted 12-month rolling average of the composite sample results collected at each POC to the surface water quality standards. The volume-weighted 30-day average of these results is also evaluated. The RFLMA Attachment 2 decision logic flowchart Figure 5, "Points of Compliance" (Appendix B), is relevant to these evaluations. An exceedance

of either calculated average is a reportable condition under RFLMA that requires consultation with EPA and CDPHE.

During this FYR period (2012-2016), there were no exceedances of constituents sampled at WOMPOC and no reportable conditions.

There were four reportable conditions for uranium at WALPOC during this FYR period: three involving the 30-day average and one involving the 12-month rolling average. The first reportable condition occurred in December 2013, when the 30-day average U concentration (16.9 µg/L) exceeded the RFLMA standard of 16.8 µg/L (CR 2014-05). Subsequent 30-day averages (17.0 to 21.9 µg/L) collected at WALPOC exceeded the standard until May 2014, when the 30-day average fell below the standard. Because the 12-month rolling average is calculated for a longer period, these 30-day averages caused the 12-month rolling average to subsequently become reportable for U in October 2014 (17.2 µg/L). The 12-month rolling average for U at WALPOC remained above the RFLMA standard until January 2015 (17.0 to 17.2 µg/L), when it fell below the standard. In January 2016, a reportable condition occurred at WALPOC when the 30-day average uranium concentration (16.9 µg/L) exceeded the RFLMA standard (CR 2016-01). Subsequent 30-day averages from routine samples collected at WALPOC remained above the standard (16.9 to 19.0 µg/L) until March 2016. From late March until early December 2016, the 30-day uranium averages were below the RFLMA standard. The 12-month rolling averages for this time period (January through early December 2016) did not exceed the standard. In early December 2016, the 30-day average for U at WALPOC (16.9 µg/L) exceeded the RFLMA standard (CR 2017-02).

Figure 5 presents the uranium data for WALPOC from 2011 through the end of 2016. For each reportable condition, DOE consulted with EPA and CDPHE and developed a plan for responding to the condition (CRs 2014-05, 2015-01, 2016-01, and 2017-02). The plans included the collection of additional surface water samples from WALPOC and locations upstream, and the addition of high-resolution isotopic uranium analyses for selected samples. Data collected prior to mid-2015 to evaluate these reportable conditions were included in a comprehensive evaluation of the distribution, transport mechanisms, sources, and isotopic composition of U in North and South Walnut Creeks (Wright Water Engineers, 2015). The report for this evaluation (without appendices) is reproduced in Appendix J. Among other things, the study suggests a predictable relationship between precipitation and U concentrations in surface water. Specifically, heavy precipitation events (1) increase the mobility of U in soil which can then migrate into groundwater, (2) increase groundwater discharge to surface water, and (3) increase U concentrations in surface water once direct runoff has diminished. Assessment of the Walnut Creek data show that significant precipitation events such as those experienced in 2013 and 2015, result in an initial lowering of uranium concentrations in surface water due to increased runoff, followed by an increase in uranium concentrations over a prolonged period due to increased mobilization of uranium via geochemical mechanisms and increased volumes of groundwater reaching surface water. This effect was seen after the September 2013 event in which 30-day average U concentrations were first detected at reportable levels in December 2013, and did not return to concentrations below the RFLMA standard until approximately five months later in May 2014 (Figure 5). As of the end of this FYR period (December 2016), the 30-day average for U is above the RFLMA standard and the 12-month rolling average for U is below the standard.

Other information considered during the RFLMA evaluation of the U reportable conditions at WALPOC included: (1) data do not suggest a new source of U contamination, (2) U concentrations at WALPOC ultimately decreased to below RFLMA standards, (3) not all U detected at WALPOC is contamination from site operations (i.e., measured U concentrations at WALPOC are an average of 75 percent naturally-occurring uranium [Wright Water Engineering, 2015]), and (5) all exceedances were well below the EPA maximum contaminant level (MCL) for U in drinking water of 30 µg/L. Although the MCLs are not directly applicable to the Site, comparison with the drinking water standard offers perspective on the quality of surface water exiting the site.

While both the 30-day average and 12-month rolling average are calculated for the POCs, RFLMA states that the 12-month rolling average is used in the evaluation of remedy performance. The evaluation of remedy performance in light of the 12-month rolling average exceedance for U at WALPOC concluded that the remedy remains protective. This conclusion was based on the following considerations: (1) the reportable condition was a short-term occurrence associated with an extreme weather event, (2) the U exceedances are not anticipated to occur with any regularity in the future, and (3) the RFLMA standard for U is based on human health risk from long-term (chronic) exposure. As such, no unacceptable exposures occurred, or are expected to occur, as a result of the reportable condition.

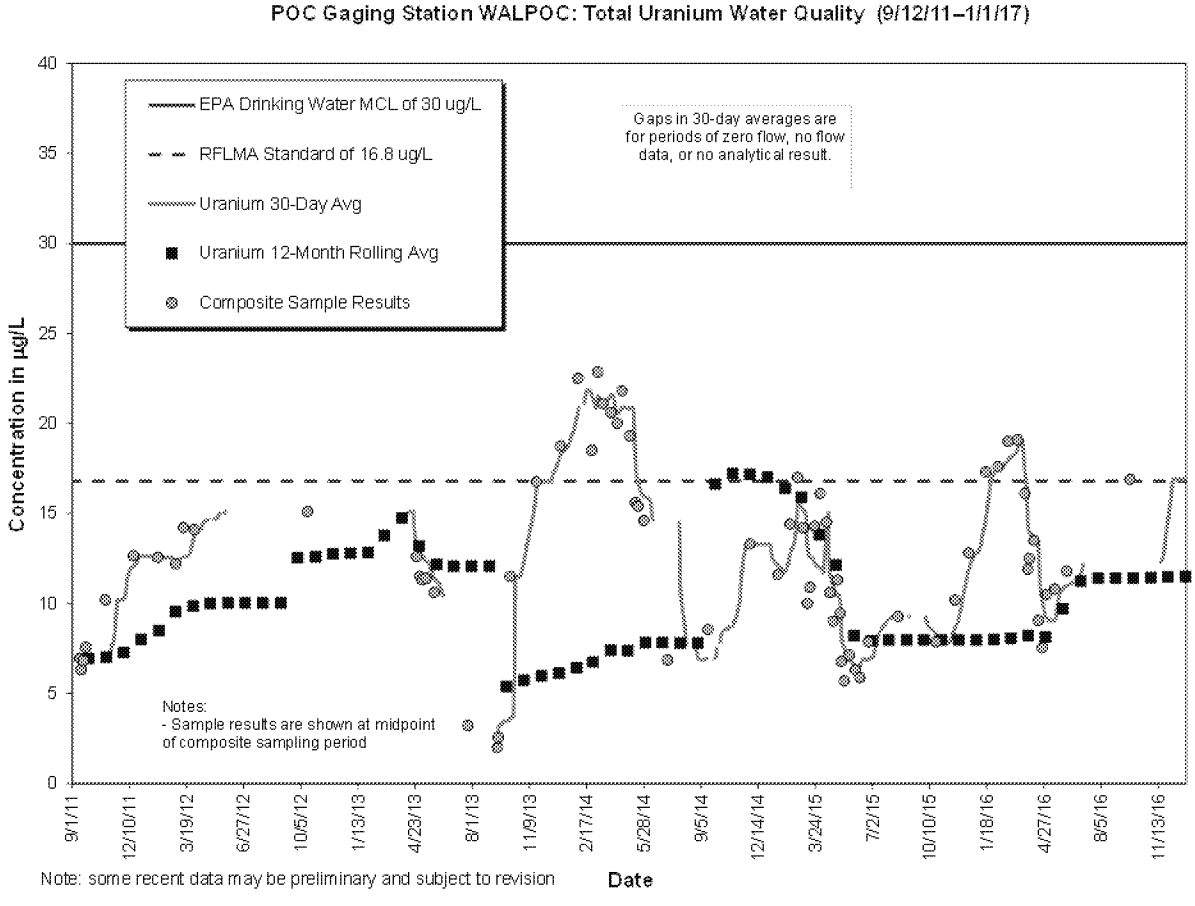


Figure 5. Uranium Concentrations at WALPOC

6.1.4 Operation and Maintenance of Remedy Components

The engineered components of the remedy include the two landfill covers and the groundwater treatment systems. The operation and maintenance of the PLF and OLF covers are directly relevant to soil RAOs 2 and 3; groundwater treatment system operation and maintenance are directly relevant to groundwater RAO 2 and soil RAO 1.

6.1.4.1 Present Landfill

The Present Landfill (PLF) was closed in 2005 and includes a RCRA-compliant composite cover, monitoring wells, and the PLF treatment system (PLFTS). The location of the PLF and PLFTS are shown in Figure 6. The PLFTS consists of a passive air stripper (an arrangement of concrete steps over which the seep water flows) designed to treat VOCs. The PLFTS treats landfill seep water, surface water runoff, and groundwater intercepted by the Groundwater Intercept System (GWIS), which was constructed to minimize upgradient flow into the PLF.

The evaluation of remedy performance at the PLF considers monitoring data from upgradient and downgradient wells (RCRA wells), the PLFTS, downstream surface water location NNG01, and information obtained in routine inspections.

The inspection frequency for the PLF is quarterly and settlement monuments are surveyed annually. The PLF inspection includes groundwater and surface water monitoring facilities, subsidence/consolidation, slope stability, soil cover, storm-water management structures, and erosion in surrounding features. No notable conditions were observed during PLF inspections during this FYR review period. Because vegetation success criteria were met at the PLF prior to the third FYR report, PLF-specific vegetation inspection requirements were discontinued at the PLF as recommended in the third FYR report (see CR 2014-03). Site-wide vegetation inspection requirements continue at the COU in accordance with the Site *Vegetation Management Plan* (DOE 2006b). The quarterly inspection frequency for other items and annual settlement monument surveying is recommended to continue.

There are three upgradient and three downgradient groundwater monitoring wells (RCRA wells) at the PLF (Figure 6). These wells are sampled for VOCs and metals on a quarterly basis. The RFLMA Attachment 2 decision logic flowchart Figure 10, "RCRA Wells" (Appendix B), is relevant to these data. RFLMA requires statistical analyses be conducted on RCRA well data from the PLF (and OLF) to compare constituent concentrations in groundwater at upgradient and downgradient wells and to determine trends in downgradient wells. These statistical evaluations are conducted annually and are presented in the corresponding RFLMA annual reports. The results of these analyses for each year in this FYR period are very similar, with several metals at higher concentrations downgradient than upgradient of the landfill, and in some cases, increasing metals concentration trends in downgradient wells. The full report of each analysis may be found in the Rocky Flats annual reports. The RFLMA parties consulted annually during this FYR period regarding these results and no actions were required other than continued monitoring and evaluation (see CR 2011-03).

RFLMA requires monitoring of the influent and effluent from the PLFTS to assess the operation of this passive treatment system. The influent and effluent locations are sampled on a quarterly basis for VOCs, metals, and U; the effluent location is also sampled for SVOCs. The RFLMA Attachment 2 decision logic flowchart Figure 11, "Groundwater Treatment Systems" (Appendix B), is relevant to these data. Arsenic and selenium were detected above RFLMA standards intermittently in PLFTS effluent throughout this FYR period, triggering additional sampling in each instance. Subsequent effluent sample results were below RFLMA standards, so consultation with the RFLMA parties was not required. Vinyl chloride was detected above the RFLMA standard in PLFTS effluent for three consecutive months in both 2014 and 2015 (CRs 2014-06 and 2015-07). Consultation with the RFLMA parties was initiated and surface water samples were collected downstream of the PLFTS at location NNG01 (Figure 6). Vinyl chloride was not detected in either of the surface water samples from NNG01. The RFLMA parties determined that no further action was required to address the vinyl chloride observations. PLFTS effluent meets RFLMA standards at the end of this review period.

The remedy at the PLF remains protective of human health and the environment. The landfill cover and stormwater management system at the PLF remain intact and effective in preventing unacceptable exposure to buried wastes. Monitoring data at the PLFTS indicate that the system is operating as designed and is generally effective in removing trace VOCs from groundwater and seeps at the landfill. While some constituents in PLFTS effluent were detected above the RFLMA standards during this FYR period, these occurrences were short-lived and did not impact downstream surface water quality.

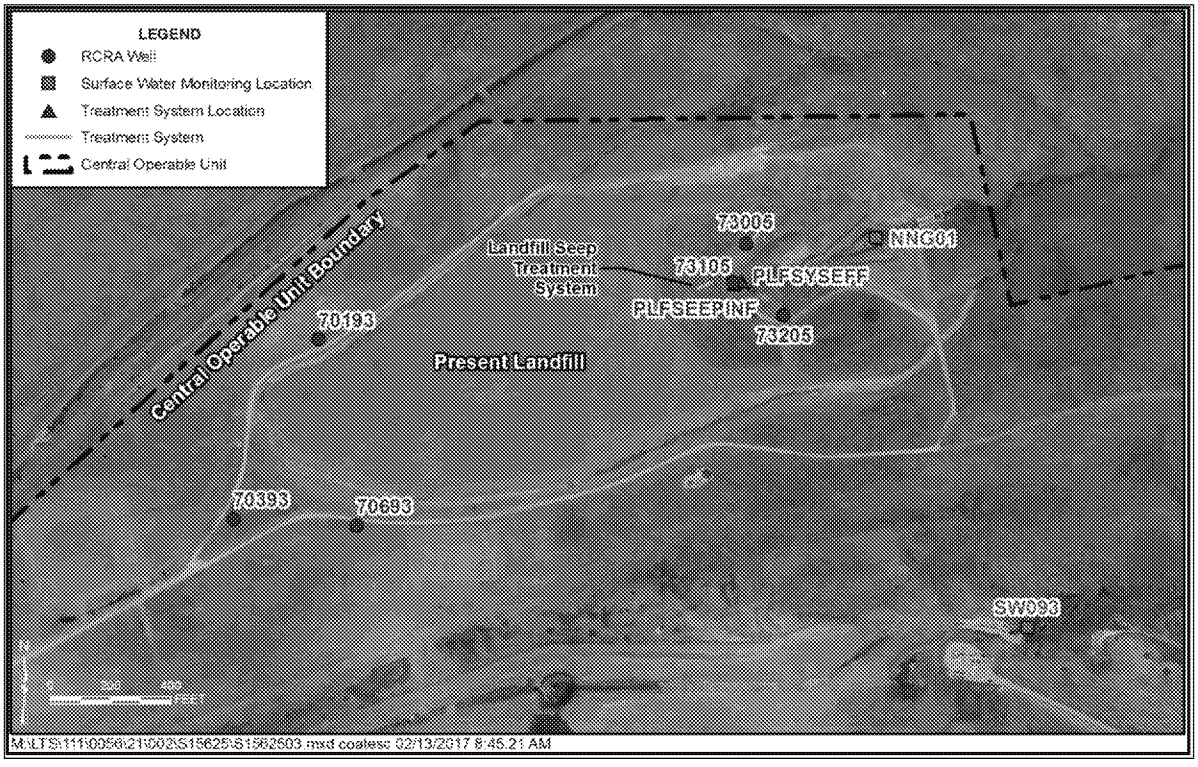


Figure 6
PLF Monitoring Locations

6.1.4.2 Original Landfill

The Original Landfill (OLF) was closed in 2005 with a soil cover and stormwater management features designed to achieve hillside stability and control precipitation run-on and runoff. The location of the OLF with respect to the COU is shown in Figure 2. The evaluation of remedy performance at the OLF considers monitoring data from upgradient and downgradient wells (RCRA wells), upstream and downstream surface water locations GS05 and GS59, and information obtained in routine inspections.

The current inspection frequency for the OLF is monthly and settlement monuments are surveyed quarterly. Additional inspections are required following specific weather events defined in RFLMA. Inspection information includes groundwater and surface water monitoring facilities, subsidence/consolidation, slope stability, soil cover, stormwater management structures, and erosion in surrounding features. Because vegetation success criteria were met at the OLF prior to the third FYR report, OLF-specific vegetation inspection requirements were discontinued as recommended in the third FYR report. Site-wide vegetation inspection requirements continue at the COU in accordance with the Site *Vegetation Management Plan* (DOE 2006b).

The natural geologic and hydrologic conditions at the OLF make it prone to slumping and settling that can be exacerbated by heavy precipitation events. These conditions have been in existence since before waste was first placed on the hillside in the early 1950s. After closure of the OLF in 2005, the hillside remained stable until 2007, when landfill inspections identified localized slumping and settling of the cover and the presence of seeps. These conditions triggered the RFLMA consultative process and are discussed in CR 2008-07 and the third FYR report (DOE 2012). The plan for addressing these conditions included repairs to the landfill and further investigation to determine if the conditions were likely to influence the integrity of the OLF cover. The resulting geotechnical investigation concluded that, according to slope stability modeling, the large scale overall slope at the OLF was stable and the risk of large scale failure of the OLF was low (TtT 2008).

Following a week-long rain event in the fall of 2013, a weather-related inspection of the OLF identified localized surface cracking and settlement on the northeastern edge of the OLF hillside. These conditions resulted in a RFLMA reportable condition for the OLF (CR 2013-02), triggering the RFLMA consultative process. Maintenance actions were taken to repair the settlement and the East Perimeter Channel (EPC) was reconfigured (CRs 2013-03 and 2014-09). Another heavy precipitation event occurred in the spring of 2015, resulting in extensive movement on the eastern edge of the OLF hillside. As with previous slumping, most of this movement occurred outside the waste footprint. Maintenance was completed in accordance with the OLF M&M Plan in the fall of 2015 (CRs 2015-03 and 2015-06). In the spring of 2016, the OLF hillside showed signs of movement in the southeast corner, outside the waste footprint. This movement was not as significant as the movement in 2015, and the regrading and repair of the EPC and berms was completed in October 2016. Subsequent evaluation determined that the East Subsurface Drain (ESSD) located in the northeast corner of the EPC was plugged and required maintenance (CR 2016-04). Repair of the ESSD was completed in early January 2017. In response to the slumping, cracking, and displacements that have occurred at the edges of the landfill, DOE-LM initiated a multifaceted effort to further evaluate and reduce the instability of the slopes surrounding the OLF. The *Original Landfill Path Forward* report was published in

January 2017 with recommendations for a phased approach to the evaluation of options for minimizing slope movement at the OLF (DOE 2017).

In summary, routine and weather-related inspections at the OLF identified substantial, localized slumping and cracking along the eastern and western edges of the landfill during this FYR period. While hillside movement was more extensive than the previous FYR period (2007-2012), the central portion of the OLF has remained stable. Repair and maintenance activities have occurred throughout this FYR period in response to OLF conditions, and will continue as necessary. While the majority of the cracking and slumping has occurred on the periphery of the OLF, the presence of seeps and some cracking has been identified within the waste footprint. The remedy at the OLF remains protective, however, because no unacceptable exposures to personnel working at the Site have occurred as a result of these conditions. Occupational exposure to personnel working at the OLF to implement the various repairs and maintenance operations is closely monitored and documented in the site records. Furthermore, groundwater and surface water monitoring data collected during this FYR period suggest the hillside instability at the OLF has not negatively affected groundwater or surface water quality in the long-term.

There are three downgradient and one upgradient groundwater monitoring wells (RCRA wells) at the OLF (Figure 7). These wells are sampled for VOCs, SVOCs, and metals on a quarterly basis. The RFLMA Attachment 2 decision logic flowchart Figure 10, "RCRA Wells" (Appendix B), is relevant to these data. As with the PLF RCRA wells, statistical analyses for OLF RCRA well data are very similar for each year within this FYR period, with several metals detected at higher concentrations downgradient than upgradient of the landfill, and in some cases, increasing metals concentration trends in downgradient wells. The full report of each analysis may be found in the Site annual reports. DOE has consulted with EPA and CDPHE annually on these results and no action has been required other than continued monitoring and evaluation (see CR 2011-03).

Monitoring at the OLF also includes the collection of surface water samples at locations upstream (GS05) and downstream (GS59) of the landfill (Figure 7). These locations are sampled at least quarterly for VOCs, uranium, and metals. The RFLMA Attachment 2 decision logic flowchart Figure 12, "Original Landfill Surface Water" (Appendix B), is relevant to these data. During this FYR period there have been three instances when downstream sample results for metals at GS59 triggered monthly sampling. In the fourth quarter of 2013, selenium was detected at 5.5 µg/L, above the RFLMA standard of 4.6 µg/L. All subsequent samples from GS59 were below the standard until the third quarter of 2015, when both selenium (6.7 µg/L) and arsenic (10.6 µg/L) were detected above the RFLMA standards of 4.6 µg/L and 10 µg/L, respectively. Subsequent samples did not exceed the selenium or arsenic standards and no further action was required. In the fourth quarter of 2016, selenium was detected at GS59 at 8.03 µg/L. Monthly sampling at GS59 will begin in January 2017. The results of surface water monitoring at the OLF for each year in this FYR period may be found in Site annual reports.

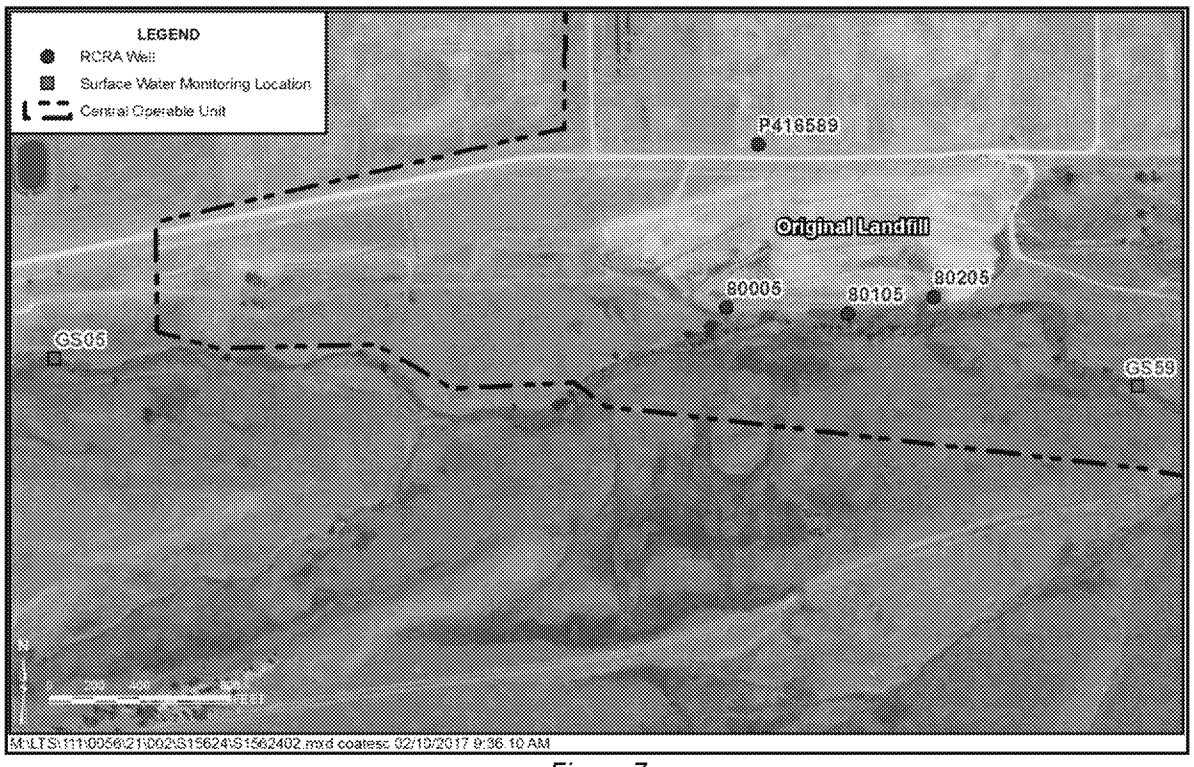


Figure 7
OLF Monitoring Locations

6.1.4.3 Groundwater Treatment Systems

The remedy in the CAD/ROD included the four groundwater treatment systems operating at the time the Site closed in 2006: Present Landfill Treatment System (PLFTS), Solar Ponds Plume Treatment System (SPPTS), Mound Site Plume Treatment System (MSPTS) and East Trenches Plume Treatment System (ETPTS). The treatment systems remove target contaminants from groundwater (VOCs, nitrate, and/or uranium) and reduce contaminant load to surface water. Each groundwater treatment system is monitored, at a minimum, for untreated influent and treated effluent, and for impacts to surface water downstream of the effluent discharge points. Monitoring data associated with the groundwater treatment systems is evaluated in accordance with RFLMA Attachment 2 decision logic flowchart Figure 11, "Groundwater Treatment Systems" (Appendix B). The discussion of influent, effluent, and surface water monitoring results for this FYR period for the SPPTS, MSPTS, and ETPTS is found in Appendix E; PLFTS monitoring data are discussed in Section 6.1.4.1.

A detailed description of each system configuration at the beginning of this FYR period may be found in the third FYR report (DOE 2012b). Several opportunities for groundwater treatment system optimization were identified and implemented during this FYR period through the RFLMA consultative process. Treatment system modifications are discussed in CRs 2012-02, 2014-01, 2014-04, 2014-08, 2015-04, 2015-08, 2015-09, and 2016-02 (Appendix D). These modifications have improved system performance during this FYR period and are expected to ultimately reduce the need to rely on certain institutional controls related to contaminated groundwater plumes and protection of surface water quality in the future. No changes to the PLFTS were made during this FYR period. A summary of treatment system changes

implemented during this FYR period is presented below; the progression of system changes following site closure may be found in the Site annual reports.

- **SPPTS.** This treatment system has been the focus of extensive study and modification since the Site closed in 2005. Evaluation of the system was necessary due to the poor performance of the original sawdust and zero-valent iron (ZVI) treatment media in meeting post-closure surface water standards and the cost and difficulty in maintaining the system. Changes to the system during this FYR period included removal of existing treatment media, conversion of the system to a full-scale bioremediation lagoon to treat nitrate, and small-scale treatability studies using ZVI to remove uranium. At the end of this FYR period, the lagoon conversion has shown promising results in the removal of nitrate. In fact, nitrate has not been detected in the last 12 consecutive weekly samples of SPPTS effluent collected through the end of 2016. Uranium treatability studies are ongoing.
- **MSPTS and ETPTS.** Each of these two systems originally utilized ZVI treatment media. While this media was effective in reducing contaminant load in groundwater, it proved less effective in consistently reducing VOCs to concentrations below the surface water standards. As with the SPPTS, media removal and disposal was also costly and labor intensive. Opportunities for VOC treatment optimization were identified and implemented for the MSPTS and ETPTS through the RFLMA consultative process. To test VOC removal potential, pilot-scale air strippers were added to MSPTS in 2011(CR 2011-01) and ETPTS in 2014 (CR 2014-01). Based on the success of the pilot-scale air strippers, the MSPTS and ETPTS were reconfigured at different times to eventually utilize a single, full-scale air stripper located at the ETPTS (CRs 2015-04, 2016-02). Following installation of the air stripper in late 2016, VOC concentrations in combined MSTPS and ETPTS effluent have met all RFLMA standards. Because this most recent reconfiguration changed the location of groundwater treatment of the Mound Site plume from the MSPTS to the ETPTS, this modification was considered a significant difference to the selected remedy for the MSPTS. The significant difference was documented in an Explanation of Significant Differences (see CR 2016-02).

  The reconfiguration of the MSPTS and ETPTS has increased the systems' resilience to climate change impacts, such as weather variability and extremes. Because the site has no line power available, the systems are powered entirely by solar energy through the use of solar panels and batteries, which are designed to limit power interruptions and allow for operation in all weather conditions. Unlike the previous gravity-fed, passive design, the reconfigured ETPTS operates in a batch treatment mode, and the air stripper treats at a constant flow rate. The result is that treatment is no longer dependent on residence time within the media and can accommodate a wide range of groundwater flows while achieving the same level of treatment. Treating the groundwater in batches ensures that groundwater processed through the system receives a consistent level of treatment. The reconfigured system provides more control over the treatment of the Mound and East Trenches groundwater plumes, thus providing additional flexibility in accomplishing groundwater plume treatment. The MSPTS, ETPTS, and SPPTS collection systems and the ETPTS and SPPTS treatment system feature remote-access monitoring capabilities that allow for the automatic and/or manual control of individual system components in response to changing conditions (e.g., increase in groundwater volumes).

6.1.5 Operations and Maintenance Costs

[Evaluation of the O&M cost information for this FYR period is in progress. A preliminary draft of the report section will be provided to the working group. The evaluation will compare site costs to the cost estimate provided in the Proposed Plan. Costs not related to remedy implementation will not be included in the evaluation. Costs for treatment system reconfiguration will be discussed from the perspective of implementing better technology. A discussion on OLF maintenance cost will also be included.]

Table 4. Fourth FYR RAO Status

RAO	Remedy	FYR Status
Groundwater		
1. Meet groundwater quality standards, which are the Colorado Water Quality Control Commission surface water standards, at groundwater AOC wells.	• GW monitoring at AOC wells	A reportable condition for TCE in AOC well 10304 occurred in 2015 (Section 6.1.2). Consultation with the RFLMA parties (CR 2015-10) resulted in a plan to evaluate the condition to ensure the remedy remains protective. At the end of this FYR period, the most recent semiannual data show a TCE concentration above the RFLMA standard at AOC well 10304. The remedy remains protective because (1) the 2016 data suggest a decreasing trend in TCE concentration in this well, suggesting a short-term event and (2) the reportable condition did not impact downstream surface water quality, as TCE was not detected downgradient of the well in Woman Creek.
2. Restore contaminated groundwater that discharges directly to surface water as base flow, and that is a significant source of surface water, to its beneficial use of surface water protection wherever practicable in a reasonable timeframe. This is measured at groundwater Sentinel wells. Prevent significant risk of adverse ecological effects.	• GW monitoring at Sentinel wells • Monitoring & maintenance of GW treatment systems • GW treatment prior to reaching SW	Sentinel well data exceeded RFLMA standards for some VOCs, nitrate, and uranium. Optimization and technical improvement opportunities at the SPPTS, MSPTS, and ETPTS were identified and implemented during this FYR period through the RFLMA consultative process (CRs 2012-02, 2014-01, 2014-04, 2014-08, 2015-04, 2015-08, 2015-09, and 2016-02). Optimization of the systems has resulted in reductions of nitrate and VOC concentrations in GW prior to reaching surface water in the Walnut Creek drainage (see Section 6.1.4.3). Optimization of the GW treatment systems will continue in accordance with CRs 2015-08, 2015-09, and 2016-02. Evaluation of groundwater treatment system monitoring is summarized in Appendix E. The ecological risk assessment conclusions remain valid and indicate that residual contamination in the COU does not present a significant risk of adverse ecological effects. No evidence of adverse biological conditions (e.g., unexpected mortality or morbidity) was observed during monitoring and maintenance activities during this FYR period (2012 – 2016).
3. Prevent domestic and irrigation use of groundwater contaminated at levels above MCLs.	ICs • Drinking/agricultural SW use prohibited. • GW well drilling prohibited. • Any activities that interfere with remedy actions prohibited except when in accordance w/ RFLMA.	This RAO was met for this FYR period. Institutional controls recorded in the environmental covenant have been effective in preventing domestic and irrigation use of groundwater from the Site. The results of RFLMA routine inspections confirm that no unauthorized intrusive activities have occurred at the Site during this FYR period (Section 6.1.1).
Surface Water		

RAO	Remedy	FYR Status
1. Meet surface water quality standards, which are the Colorado Water Quality Control Commission surface water standards.	• SW monitoring at POCs	The WALPOC 12-month rolling average for U exceeded the RFLMA standard for a 4-month period in 2014/2015 (Section 6.1.3). Consultation with the RFLMA parties (CR 2015-01) resulted in a plan to evaluate the condition to ensure the remedy remained protective. Evaluation of the Walnut Creek drainage system suggests that the increase in U concentrations may be attributable to heavy precipitation events which increase the mobility of U and increase the volume of groundwater discharged to surface water (Wright Water Engineers, 2015). The remedy remains protective because (1) the reportable condition was a short-term occurrence associated with an extreme weather event, (2) the U exceedances are not anticipated to occur with any regularity in the future, and (3) the RFLMA standard for U is based on human health risk from long-term (chronic) exposure. As such, no unacceptable exposures occurred, or are expected to occur, as a result of the reportable condition.

RAO	Remedy	FYR Status
Soil		
1. Prevent migration of contaminants to groundwater that would result in exceedances of groundwater RAOs.	• GW monitoring at Sentinel wells • GW treatment prior to reaching SW	Sentinel well data exceeded RFLMA standards for some VOCs, nitrate, and uranium. Optimization and technical improvement opportunities at the SPPTS, MSPTS, and ETPTS were identified and implemented during this FYR period through the RFLMA consultative process (CRs 2012-02, 2014-01, 2014-04, 2014-08, 2015-04, 2015-08, 2015-09, and 2016-02). Optimization of the systems has resulted in reductions of nitrate and VOC concentrations in GW prior to reaching surface water in the Walnut Creek drainage (see Section 6.1.4.3). Optimization of the GW treatment systems will continue in accordance with CRs 2015-08, 2015-09, and 2016-02. Evaluation of groundwater treatment system monitoring is summarized in Appendix E.
2. Prevent migration of contaminants that would result in exceedances of surface water RAOs.	• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components	This RAO was met for this FYR period. Institutional controls are in place to prohibit soil disturbance without appropriate controls. Inspection and monitoring at the PLF indicate that the landfill cover and stormwater management system remain intact and effective in preventing unacceptable exposure to buried wastes. The PLFTS is operating as designed and is generally effective in removing trace VOCs from groundwater and seeps at the landfill. And, although some constituents in PLFTS effluent were detected above the RFLMA standards during this FYR period, these occurrences were short-lived and did not impact downstream surface water quality. A reportable condition relating to the effectiveness of the OLF cover was detected in 2013. The RFLMA parties consulted on this condition multiple times throughout this FYR period and several repairs to the OLF stormwater management system were completed (Section 6.1.4.2) and additional actions are planned. The remedy at the OLF remains protective because (1) the cover remains intact and effective in preventing unacceptable exposure to buried wastes and (2) groundwater and surface water monitoring data collected during this FYR period do not suggest the hillside instability at the OLF has negatively affected groundwater or surface water quality in the long-term.
3. (Part 1) Prevent exposures that result in an unacceptable risk to the WRW. The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at the site or multiple pathways of exposure (40 Code of Federal	• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components ICs: • Perimeter signage • Activity restrictions	This RAO was met for this FYR period. The land use and exposure assumptions for a wildlife refuge worker (WRW) used in the CRA remain valid and human health risk remains below the 10^{-6} risk level (Section 6.2.2). Institutional controls and physical controls to prevent unacceptable exposures, including via the indoor air pathway, are in place and effective (Section 6.1.1).

RAO	Remedy	FYR Status
Regulations 300.430[e][2][i][A][2]).	• GW use restrictions • Digging restrictions • Construction restrictions	See PLF, PLFTS, and OLF status in Soil RAO 2 above.
(Part 2) Prevent significant risk of adverse ecological effects.	• Repair and maintenance of landfill covers, vegetation • Ongoing protection of remedy components	This RAO was met for this FYR period. The ecological risk assessment conclusions remain valid and indicate that soil conditions do not represent a significant risk of adverse ecological effects at the COU. No evidence of adverse biological conditions (e.g., unexpected mortality or morbidity) was observed during monitoring and maintenance activities during this FYR period (2012 – 2016). See PLF, PLFTS, and OLF status in Soil RAO 2 above.

6.2 Question B: Are the Exposure Assumptions, Toxicity Data, Cleanup Levels, and RAOs Used at the Time of the Remedy Still Valid?

Based on the evaluation presented in this section, the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy are still valid and revision of the RAOs is not necessary. There were no changes in exposure pathways or assumptions during this FYR period; land use in the COU remains consistent with the Rocky Flats Wildlife Refuge land use assumption in the CAD/ROD. There were some revisions to surface water quality standards and toxicity data, which are discussed in the sections below.

6.2.1 Evaluation of Changes in Standards

A review of the CAD/ROD ARARs was conducted to determine whether there have been any promulgated changes to statutes or regulations relevant to the chemicals, location, and/or action addressed by the CAD/ROD during this FYR period. Appendix H is a table of changes to CAD/ROD ARARs and other potentially applicable regulations that were considered in this FYR evaluation.

The remedy performance standards for surface water and groundwater at the Site are the Colorado surface water quality standards identified as ARARs in the CAD/ROD. These standards are directly relevant to groundwater RAOs 1 and 2, surface water RAO 1, and soil RAOs 1 and 2 (Table 4). The CAD/ROD also identified select Colorado radiation protection standards as ARARs for the Site. Changes to ARARs may impact remedy protectiveness and must be evaluated in the FYR process.

6.2.1.1 Surface Water Standards

The surface water standards applicable to the COU are based on (1) Colorado WQCC regulation # 31, "Colorado Basic Standards and Methodologies for Surface Waters" (5 CCR 1002-31), which are statewide basic standards, and (2) Colorado WQCC regulation #38, "Classification and Numeric Standards South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin" (5 CCR 1002-38), which are site-specific standards. The Walnut and Woman Creek portions in the COU are Big Dry Creek segments 4a and 5 of the South Platte River Basin. Because the use classification of groundwater in the COU is surface water protection, the applicable surface water standards also apply to groundwater.

The surface water standards for eight chemical constituents were revised within this FYR period (see CR 2012-03). The standards for five of these constituents (acrylamide, carbon tetrachloride, hexachloroethane, nitrobenzene, and tetrachloroethene) increased and therefore, do not affect remedy protectiveness. The standard for *cis*-1,2-dichloroethene was changed to a range of concentrations (0.014 to 0.070 mg/L). As a result of consultation with the RFLMA parties, the higher number in the range (0.070 mg/L) was retained as the RFLMA surface water standard. The higher standard was the same as the previous RFLMA standard for *cis*-1,2-dichloroethene, therefore, remedy protectiveness was not affected. The standards for two constituents (1,4-dioxane and pentachlorophenol) decreased from the previous standards. These two constituents were not identified as analytes of interest in any media at the Site in the RI/FS report (DOE 2006a), nor were they identified as COCs in the CRA. Therefore, regular monitoring for these constituents is not required by RFLMA. Limited data from groundwater and treatment system

monitoring during this FYR period show pentachlorophenol as non-detect in all samples; no data for 1,4-dioxane is available. There is no evidence to suggest a previously unidentified source of 1,4-dioxane or pentachlorophenol is present at the Site. Therefore, a change in the standards for these two constituents does not affect protectiveness of the remedy.

6.2.1.2 Radiation Protection Standards

For radiological sites that do not allow for unrestricted use, as is the case for the COU, Colorado regulations require that institutional controls be in place that reasonably assure that the total effective dose equivalent from residual radioactivity at the site does not exceed 25 mrem/year (6 CCR 1007-4.61.2). In 2006, a dose assessment was completed for the COU to determine if the Site met the 25 mrem/year dose criteria upon closoure (DOE 2006). For this FYR, changes to input parameters (e.g., slope factors, dose conversion factors) used in the dose assessment were reviewed to determine if this ARAR continues to be met. [Add discussion of radiological dose assessment and how it relates to protectiveness.]

6.2.2 Evaluation of Changes in Toxicity Data

The remedy performance standards for soil in the COU are site-specific, risk-based values calculated using the exposure assumptions for a wildlife refuge worker (WRW). These standards, referred to as preliminary remediation goals (PRGs), were used to identify COCs at the site and are directly relevant to the evaluation of soil RAO 3 (Table 4). The risks posed by the COCs left at the Rocky Flats Site following accelerated actions were evaluated in a comprehensive risk assessment (CRA) in 2006 (DOE 2006a).

The CRA evaluated the land area that encompasses the POU and the COU, divided into twelve exposure units (EUs) (Figure C-1). The CRA was completed by EU and not by OU (POU and COU). However, the RI/FS and CAD/ROD concluded that the POU was not affected by site activities from a hazardous waste perspective (DOE, 2006a; DOE, EPA, CDPHE 2006). There have been no changes or new information since the CAD/ROD that would alter this conclusion. Therefore, it is assumed that the chemical COCs apply to the COU portion of the site and not the POU. Under CERCLA, the FYR risk assessment review is required for the COU as part of the protectiveness evaluation.

Table 5 summarizes all COCs (chemical and radiological) for each EU for which risks were evaluated in the CRA. These are constituents for which residual soil concentrations exceeded site PRGs.

The PRGs represent concentrations for individual chemical constituents and radionuclides that would equate to a carcinogenic risk of 1×10^{-6} or a noncarcinogenic hazard quotient of 0.1 based on the exposure assumptions for the WRW. The PRGs were developed using toxicity data that were current at the time of the CRA and were developed for exposures to both surface and subsurface soils. Changes to the risk parameters (e.g., slope factors, toxicity data) used to calculate these PRGs may impact remedy protectiveness and must be evaluated in the FYR process.

Table 5
Surface Soil COCs Identified for Each EU in the CRA

	Exposure Unit											
Constituent	**Industrial Area EU**	**Upper Woman Drainage EU**	**Wind Blown EU**	**No Name Gulch EU**	**Upper Walnut Drainage EU**	**Lower Woman Drainage EU**	**Rock Creek EU**	**Lower Walnut Drainage EU**	**Inter Drainage EU**	**West Area EU**	**Southwest Buffer Zone Area EU**	**Southeast Buffer Zone Area EU**
Arsenic	X	-	X	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	X	-	-	-	-	-	-	-	-
2,3,7,8-TCDD	-	X	-	-	-	-	-	-	-	-	-	-
Benzo[a]pyrene	X	X	-	-	X	-	-	-	-	-	-	-
Plutonium 239/240	-	X	-	-	-	-	-	-	-	-	-	-

"X" = constituent designated a COC in the 2006 CRA.
"-" = constituent not designated a COC in the 2006 CRA.

6.2.2.1 Chemical Constituents

The COC identification process used in the CRA was reviewed using updated EPA soil screening values comparable to the WRW PRGs. Generally, the evaluation confirmed that the surface soil COCs identified in the CRA remain the primary risk drivers at the site. It also confirmed that there are no subsurface COCs. The toxicity data for the COCs were reviewed by comparing current toxicity data with that used during the CRA. A comparison of the CRA and current toxicity data is provided in Table 6.

Table 6
Comparison of COC Toxicity Values

COC	Carcinogenic Toxicity Values				Noncarcinogenic toxicity values			
	Oral/Ingestion[a]		Inhalation		Oral/Ingestion[d]		Inhalation	
	CRA	Current	CRA[b]	Current[c]	CRA	Current	CRA	Current[e]
Arsenic	1.50E+00	1.50E+00	1.51.E+01	4.3E-03	3.00E-04	3.00E-04	n/a	1.5E-05
Vanadium	n/a	n/a	n/a	n/a	1.00E-3	9.00E-03	n/a	n/a
Benzo(a)pyrene	7.3E+00	7.3E+00	3.1E+00	1.1E-03	n/a	n/a	n/a	n/a
2,3,7,8-TCDD	1.5E+05	1.3E+05	1.5E+05	3.8E+01	n/a	7.0E-10	n/a	4.8E-08

[a]oral slope factor $(mg/kg\text{-}day)^{-1}$
[b]Inhalation slope factor $(mg/kg\text{-}day)^{-1}$
[c]Inhalation unit risk $(ug/m^3)^{-1}$
[d]Oral Reference dose (mg/kg-day)
[e]Reference concentration (mg/m^3)

There have been some changes in toxicity data since the CRA; however, these do not affect the protectiveness of the remedy. EPA has revised their methodology for determining risks associated with the inhalation pathway for both carcinogens and noncarcinogens. However, for chemical constituents, this pathway is of much lesser importance for the WRW than the oral ingestion pathway, and does not impact the estimation of overall site risks. The toxicity data for the oral ingestion pathway has not changed for arsenic and benzo(a)pyrene. The EPA oral

reference dose for vanadium is higher than that used in the CRA, meaning that current estimated risks would be lower. A new reference dose has been added for dioxin (2,3,7,8-TCDD) since the CRA. However, the elevated concentrations of dioxin were associated with the OLF prior to construction of the cover and are no longer at the surface. Thus, the pathway to residual dioxin contamination has been severed and changes in toxicity data do not affect remedy protectiveness.

6.2.2.2 Radionuclides

[ADD section regarding radionuclide risk assessment.]

6.2.3 FYR Risk Evaluation Summary

- Exposure assumptions used are conservative and remain valid.
- The general Site Conceptual Model and assumption that the most likely exposure scenario for a human receptor is approximated by a WRW scenario is still valid for the COU.
- [Add statement about POU UU/UE]
- The changes in some toxicity values should not affect the protectiveness of the remedy.
- Institutional controls are in place at the COU that eliminate the vapor intrusion pathway.
- RAOs and cleanup goals remain valid and are not affected by updated guidance and toxicity data as long as institutional controls remain in place.

[Add radionuclide summary bullets for COU, POU, and OU3]

6.2.4 RAO Status

The status of each RAO during this FYR period is presented in Table 4. The RAOs and ARARs in the CAD/ROD remain relevant in addressing residual contamination and potential exposure pathways at the Site and assessing remedy protectiveness. Not all RAOs were met during this FYR period, however, the remedy is designed to achieve all RAOs in the long-term. No revisions to the RAOs established in the CAD/ROD are recommended.

6.3 Question C: Has Any Other Information Come to Light That Could Call Into Question the Protectiveness of the Remedy?

No other information collected during this FYR period has called into question the protectiveness of the remedy.

The robustness of the remedy, however, was tested during this FYR period by the high variability in precipitation from year to year. In 2012, the Site experienced one of the driest years on record, followed in 2013 by a significant precipitation event and subsequent flooding, and a very wet spring in 2015. During 2013, the precipitation measured in the second and third quarters (13.86 inches) was 68.9 percent higher than historical (1997–2012) values for this time period. Much of this increase is due to a significant rain event and associated flooding that occurred September 11 through September 15, 2013 (DOE 2014). Most of the precipitation in 2015 was from multiple rain storms that occurred between April and July, when almost three

quarters of the total precipitation measured in 2015 was received; slightly over half of the annual moisture fell in the months of May and June (DOE 2016). It should be noted that this precipitation information is based on data from unheated rain gages located in the COU and likely underestimate precipitation because snowmelt is not fully represented. The 2013 and 2015 precipitation events greatly increased the volume of surface water flow, as measured at the POCs (Figure 8) and the volume of groundwater treated in the groundwater treatment systems (Table 7).

6.3.1 Surface Water Flow and Runoff

The extreme variability in precipitation can be seen in the annual discharge volumes measured at WOMPOC and WALPOC (Figure 8). In spite of a very dry year (2012), a significant flooding event (2013), and a very wet spring (2015), the 12-month rolling averages at WOMPOC and WALPOC were below RFLMA surface water standards for the majority of this FYR period. In fact, there was only one short period in 2014/2015 that the 12-month rolling average exceeded the RFLMA standard at a POC. This occurred at WALPOC and may be attributed, in part, to the precipitation event in 2013. It should be noted that the maximum 12-month rolling average for uranium at WALPOC (17.2 µg/L) was only slightly above the the RFLMA standard of 16.8 µg/L.

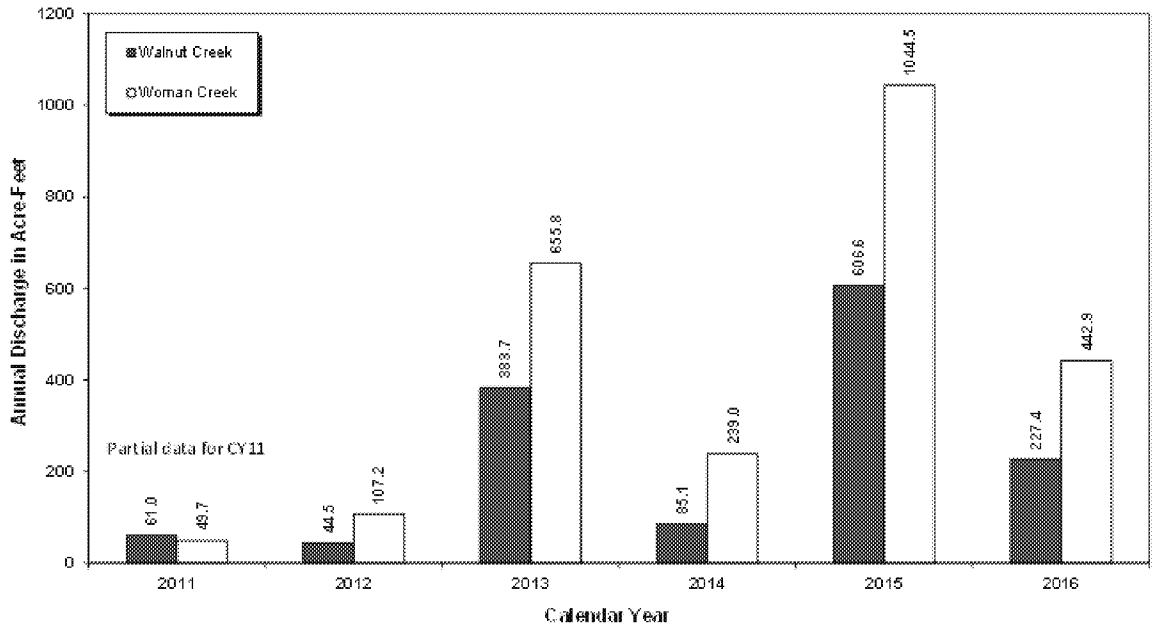


Figure 8
Annual Surface Water Discharge from WOMPOC and WALPOC

6.3.2 Groundwater Treatment Systems

The precipitation events in late 2013 and in 2015 led to increased groundwater flow to the groundwater treatment systems. While the 2013 event did not contribute as much recharge to the groundwater because so much of it ran off as surface flow, a substantial amount infiltrated and

contributed to the groundwater. The effects of this precipitation on treatment system volumes were notable in 2014, as shown on Table 7 below. The more prolonged precipitation in 2015 was much more effective in contributing to the groundwater, also as shown on this table.

These sharp increases in flow resulted in decreases in residence time within the reactive media in these treatment systems, and therefore reduced contact time of contaminants with the media. Even so, the treatment systems continued to remove the bulk of the contaminants. Note that by mid-January 2015, the ETPTS had been converted from a reactive media-based treatment approach to a commercial air stripper that is better able to accommodate changes in flow conditions without affecting treatment (see Section E1.1.2.3). The SPPTS did not perform as desired, but upgrades completed in mid-2016 were successful in achieving essentially complete treatment of the nitrate in SPPTS influent by the end of the year (see Section E1.1.2.1).

Table 7
Volume of Groundwater Treated at MSPTS, ETPTS, and SPPTS[a]

	MSPTS	ETPTS	SPPTS
Year	Estimated Annual Volume Treated (gallons)		
2000	258,000	1,633,000	64,000
2001	119,000	1,900,000	424,000
2002	53,000	1,000,000	5,600
2003	82,000	2,100,000	340,000
2004	86,000	1,500,000	230,000
2005	506,000	1,800,000	140,000
2006	430,000	675,000	251,000
2007	326,000	951,000	244,000
2008	358,000	629,000	280,000
2009	287,000	406,000	524,000
2010	420,000	1,606,000	738,000
2011	546,000	890,000	507,000
2012	461,000	622,000	498,000
2013	422,000	604,000	498,000
2014	689,000	1,298,000	591,000
2015	981,000	2,030,000	1,094,000
2016	571,000	1,799,000	459,000

[a] The estimated volume of water treated in the PLFTS is not shown because the flow data at this treatment system is not collected continuously and is not directly comparable to the other treatment system data.

6.3.3 OLF

The 2013 precipitation and subsequent flooding resulted in unusually high groundwater levels that ultimately caused portions of the periphery of the OLF to slump. The stormwater management system was further stressed by the very wet spring in 2015. Although there has been cracking and slumping in the eastern edge of the OLF hillside over the last several years, these occurrences have been primarily outside the waste footprint, and the central portion of the OLF has remained stable. Nevertheless, the conditions at the OLF warrant additional evaluation

in order to identify long-term measures that will address the reportable condition and ensure the continued protectiveness of the remedy.

7.0 Issues, Recommendations, and Follow-Up Actions

This fourth FYR did not identify any early indicators of potential remedy problems or other issues. Key aspects of remedy implementation are timely evaluation of the data in accordance with decision rules specified in RFLMA, reporting conditions that require an action determination and consultation with the RFMLA regulatory agencies to decide what, if any, mitigating actions should be taken and the schedule for the actions. As a result of the successful implementation of the RFLMA consultative process during this FYR period, potential issues and opportunities for optimization were identified and addressed as they were encountered. This process ensures that issues are addressed and resolved as they arise and are not reserved for evaluation in the next five-year review cycle.

8.0 Protectiveness Statement

The remedy at the COU is protective of human health and the environment. Institutional and physical controls are in place and effective in preventing unacceptable exposures. Although the RAOs for surface water and groundwater were not continually met at every location within the COU during this FYR period, such conditions were predicted and may be attributed in part, to the increased precipitation encountered in 2013 and 2015. The intermittent increases in specific constituent concentrations in surface water and groundwater were not attributed to a new contaminant source or a flaw in the site conceptual model and are not part of long-term, increasing trends.

Because the POU and OU3 continue to meet the conditions for UU/UE and the remedy in place at the COU is protective, the Rocky Flats Site is protective of human health and the environment.

9.0 Next Review

Contaminants at the COU are expected to remain at levels that do not allow UU/UE and will require continued remedy implementation for the foreseeable future. Thus, a fifth five-year review will be required. The next five-year review report will be submitted to EPA for concurrence in 2022.

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